FDI, R&D and Endogenous Productivity Asymmetries

Armando J. Garcia Pires *
Norwegian School of Economics and Business Administration

August 4, 2010

Abstract

We analyze the influence of endogenous productivity asymmetries between firms, in terms of competitiveness and size, on multinational activity. In the model, productivity depends on cost-reducing R&D investment. We then show that when firms differ on commitment power in R&D, the R&D leader, independently of being a multinational or a domestic firm, tends to invest more in R&D than the R&D follower. As a result of these productivity advantages, the R&D leader can more easily become multinational, because it has larger economies of scale in multinational activity. Therefore, in addition to the proximity-concentration trade-off, we identify another FDI determinant: technological competition.

Keywords: Market Structure, R&D Investment, Multinationals, Endogenous Asymmetric Firms.

JEL Classification: F23, C72, L11.

---

*This paper has benefited greatly from discussions with Gianmarco Ottaviano, Peter Neary and Renato Flôres. I am also grateful to Francesca Sanna-Randaccio, Jan I. Haaland, Leo Grünfeld, Paula Fontoura, Pedro Pontes and Victor Norman for helpful comments during the preparation of this work. The usual disclaimer, however, applies.

†Address for correspondence: Norwegian School of Economics and Business Administration, Department of Economics, Helleveien 30, N-5045 Bergen, Norway. Tel: +(47)55959622; Fax: +(47)55959543; E-mail: armando.pires@nhh.no.
1 Introduction

The motivation for this paper comes from two central ideas in the foreign direct investment (FDI) literature: first, the proximity-concentration trade-off; and second, knowledge capital as a source for the existence of multinational firms (MNFs)\(^1\).

Horstmann and Markusen (1992) were the first to propose the proximity-concentration trade-off to explain horizontal FDI (see also Rowthorn, 1992)\(^2\). They showed that firms have more incentives to concentrate production in the domestic market (domestic firm strategy) when economies of scale at the plant level are high. In turn, proximity to consumers (multinational strategy) becomes more important when the economies of economies of scale at the firm level are high. In addition, high trade costs favor the proximity option in relation to the concentration one. Therefore, the multinational option is preferred when plant specific fixed costs are low relatively to trade costs and firm specific fixed costs\(^3\). As a result, multinationals tend to be bigger in size, because by avoiding trade costs they have higher sales than exporters in the destination market. Girma and Görg (2006) call the previous the "size effect" advantage of becoming a multinational.

The knowledge capital theory starts from the stylized fact on foreign direct investment (FDI): multinational activity tends to be more important in industries and firms that have high levels of R&D to sales (see Markusen, 1995, 2002 and Markusen and Maskus, 2004)\(^4\). Motivated by the empirical

\(^1\) FDI refers to investment in which a firm in one country directly controls or owns a subsidiary in another country. A MNF is a firm that owns a significant equity share of at least one company operating in a foreign country.

\(^2\) FDI is usually divided into horizontal and vertical FDI. Horizontal FDI refers to foreign production of products that are similar to those that the MNF produces in its home market. Vertical FDI occurs when a MNF fragments internationally the production process by stages of production. Horizontal FDI is more important in the data than vertical FDI (see Markusen, 2002).

\(^3\) Brainard (1997) presents evidence for the proximity-concentration trade-off.

\(^4\) For example, according to UNCTAD (2005), 700 MNFs represent 46% of world R&D and 69% of world business R&D. Doms and Jensen (1998), in turn, show that U.S. plants owned by MNFs are more technology intensive than non-MNFs plants, and are as a result the former are more productive than the latter. Also, Bernard et al. (2004) present evidence that U.S. based MNFs have consistently performed about 2/3 of all U.S. private-sector research and development (R&D) despite accounting for barely 1/20th of 1% of all firms. For more evidence see also Grubaugh (1987), Morck and Yeung (1992) and Lin and Yeh (2005).
evidence on FDI and innovation, Markusen (2002) and Carr, et al. (2001) developed the “knowledge capital” model. The crucial assumption in this model is that MNFs are particularly knowledge intensive relative to purely domestic firms. As a consequence, MNFs arise largely because of the desire (and ability) to deploy firm specific knowledge assets in multiple countries despite the coordination and set up costs of multi-plant production. Girma and Görg (2006) label the previous the "technological effect" advantage of becoming a multinational.

The knowledge capital model, however, does not model explicitly R&D investment, and therefore knowledge is inside a black box. Petit and Sanna-Randaccio (2000) takes this into consideration and ads process R&D to Horstmann and Markusen’s (1992) horizontal FDI model. In this set up, they demonstrate that MNFs invest more in R&D than domestic firms (i.e.: MNFs are more productive than domestic firms). The rationale for this result is that MNFs have preferable access to foreign markets than domestic firms, therefore, the former have larger economies of scale in R&D than the latter. In other words, in Petit and Sanna-Randaccio (2000) the knowledge advantage of MNFs works through the “size effect”.

The heterogeneous firms literature (see for example Melitz, 2003), in turn look to the effects of (exogenous) productivity differences across firms on multinational choice. For instances, Helpman et al. (2004) develops a FDI model based on Melitz (2003). They show that only the more productive firms become MNFs, while the less productive ones either do not enter the market or are relegated to the domestic strategy. This is so since only the more productive firms can pay for the extra costs of multinational activity. However, like in the knowledge capital model R&D is not explicitly take into account and the productivity differences are not explained. Also like in Petit and Sanna-Randaccio (2000) the productivity advantages of MNFs arise from “size effects”.

We then have the productivity and size advantages of MNFs are explained from one side on the “size effects” that capture the role of changes in scale economies, and from other side the “technology effect” that focus instead on MNFs’ firm specific assets (such as know how and technology). The available empirical evidence (see Girma and Görg, 2006), however, gives more support to the technological view rather than to the size one, i.e.: MNFs’ productivity and size advantages are generated by technological effects.

In fact, as summarized by Criscuolo et al. (2004): first, globally engaged firms generate more knowledge output than do domestic firms; second, the
previous evidence is explained partly by the fact that globally engaged firms employ more knowledge inputs; third, the hypothesis that all firms have access to the same stock of worldwide knowledge is wrong. In other words, while the knowledge capital model seems to be correct in asserting that multinationals are more knowledge intensive and therefore more productive than domestic firms (as is also the case in the heterogeneous firms literature), it is essential to understand why the former gain a competitive edge over the latter in developing new knowledge.

In this sense, the aim of this paper is threefold: first, to put forward an explanation for MNFs’ advantage on R&D investment; second, to endogenize competitiveness asymmetries between firms; and third, to analyze the influence of endogenous productivity asymmetries between firms, in terms of competitiveness and size, on multinational activity.

In order to do this, we develop a duopoly FDI game with two firms that compete on outputs and R&D and decide on the mode of foreign expansion (export versus FDI). In particular, our model has three building blocks. First, we adopt Horstmann and Markusen’s (1992) horizontal FDI model. As a consequence, our model is also going to produce the proximity-concentration trade-off. Second, we introduce process R&D, which reduces marginal costs but increases fixed costs (see Leahy and Neary, 1997). In this sense, like in Petit and Sanna-Randaccio (2000), we have increasing returns on R&D investment, since larger firms can more easily pay for the fixed costs of innovation. Third, following Garcia Pires (2009), firms have differences in commitment power in R&D. Commitment power differences are linked with von Stackelberg’s (1934) first mover advantages. The difference here is that these leader advantages are not on outputs (as in von Stackelberg, 1934) but on R&D. As we are going to see, this has important consequences in the results of our paper. In particular, we are going to show that the R&D leader tends to invest more in R&D than the R&D follower, independently of “size effects”, and therefore has more chances to become a multinational. Therefore, we generate FDI and endogenize competitiveness asymmetries between firms via a “technological effect”: differences in commitment power in R&D.

The rest of the paper is organized as follows. In the next section, we introduce the base model and define commitment power in R&D. After, we derive the production equilibrium. In the fourth section, we analyze how R&D and multinational activity affect firms’ productivity level. In the fifth section, we compute profits under the different market structure configurations and perform some comparative static exercises. Then, in the sixth section we
derive the entry equilibrium. We conclude by discussing results.

2 The Model

We consider an industry with two potential producer countries (home and foreign) and a third consumer country where all production is sold\(^5\). Each country can potentially host one firm, the home firm and the foreign firm. The home and the foreign firm, in case of entry, will produce the same homogeneous good but have to decide the location of the production plant. The production plant, can be located in either the firms’ origin country (at home for the home firm and at foreign for the foreign firm) or in the third market. In the first case, a firm becomes a domestic firm while in the second case a firm becomes a multinational firm. Accordingly, when a firm chooses the domestic strategy it serves the third market through exports, while when a firm opts for the multinational strategy it serves the third market through local production.

Since the model is symmetric, in most of the following we concentrate our attention in the home country (and the home firm). Equations for the foreign country (and for the foreign firm) apply by symmetry. Foreign variables are indicated by an asterisk.

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

\[
P_{i;j} = a - b \left( q_{i;j} + q^*_{i;j} \right)
\]  

where \( q \) is the sales of the home firm in the third market and \( q^* \) is the equivalent for the foreign firm. The sub-scripts \((i,j)\) represent market structure. In particular we have that \( i = 0, E, M \) is the international strategy of the home firm, where 0 stands for non entry, \( E \) for the exporting strategy and \( M \) for the multinational strategy. Similarly \( j = 0, E, M \) is the international strategy of the foreign firm\(^6\). Also, \( a \) and \( b \) are the intercept of demand and

\(^5\)This modeling strategy is usually called the third market model (see Brander and Spencer, 1985). The third market assumption is made in order to abstract from domestic consumption.

\(^6\)Then, for example, \( q_{M,E} \) is the home firm’s sales in the third country when the home firm is a multinational and the foreign firm is an exporter (similarly \( q^*_{M,E} \) is the foreign firm’s exports to the third country when the home firm is a multinational and the foreign firm is an exporter).
an inverse measure of market size, respectively.

Like in Leahy and Neary (1997), the home and the foreign firm invest in process R&D that reduces marginal costs \((C)\) but increases fixed costs \((\Gamma)\)\(^7\). For the home firm this amounts to:

\[
C_{i,j} = (c - \theta k_{i,j}) \\
\Gamma_{i,j} = \gamma \frac{k_{i,j}^2}{2}
\]

(2)

where \(k\) is R&D investment by the home firm, \(\theta\) is the cost reducing effect of R&D, \(\gamma\) 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 \(\gamma = \gamma^*\). The symmetry in technology is assumed so that productivity asymmetries between the home and the foreign firm can only arise endogenously.

We model multinational activity similar to what is standard in the FDI literature (see Horstmann and Markusen, 1992). First, we assume that it is more costly to operate a plant in the third market (multinational firm) than in the country of origin of the firm (domestic firm)\(^8\). We then have that in order to establish a production plant, firms incur in a plant specific fixed cost, \(\Delta\), that equals \(G\) when a firm is an exporter and \(\rho G\), with \(\rho > 1\), when a firm is a multinational, i.e.: \(\Delta_E = G\) and \(\Delta_M = \rho G\). Second, when selling in foreign markets, MNFs face lower trade costs than exporters\(^9\). To be more precise, we introduce a trade cost \(t\), which is equal for the home and the foreign firm (i.e.: \(t = t^*\)), since we do not want to give an advantage on trade costs to any firm\(^{10}\). However, like in Horstmann and Markusen (1992), only exporters incur in trade costs, i.e.: \(t_E = t > 0\) and \(t_M = 0\).

\(^7\)Contrary to Horstmann and Markusen (1992), we then endogenize the firm specific fixed costs. This is particularly important, since firm specific fixed costs intend to represent, as discussed in the introduction, strategic assets, such as R&D investment, which can hardly be seen as exogenous.

\(^8\)The rationale behind this assumption can for example be that plants in foreign markets are far away from headquarters and therefore they do not have the benefits of face-to-face contact as plants that are located in the domestic market close to the headquarters. Other reasons, can be lack of knowledge of the destination market business culture and social customs.

\(^9\)The idea is that MNFs by producing in the destination market and therefore being closer to final consumers than exporters incur in lower rates of transportation.

\(^{10}\)In fact, as shown by Krugman (1984) if one firm has a trade cost advantage this can act as R&D promotion. This is so because the firm that faces lower trade costs by having preferred access to demand markets it can more easily pay for the costs of innovation.
In this sense the home firm’s profits can be written as:

\[ \Pi_{i,j} = (P_{i,j} - C_{i,j} - t_i) q_{i,j} - \Gamma_{i,j} - \Delta_i \]

### 2.1 Commitment Power in R&D

The assumption of firms with different levels of commitment power is at the heart of the Stackelberg output leader-follower model (von Stackelberg, 1934). However, Stackelberg leader advantages are not very commonly used in R&D models. The standard assumption is to have firms with the same level of commitment power in R&D (Leahy and Neary, 1997). In this paper, in turn, we apply the idea of differences in commitment power to R&D.

The concept of commitment power refers to the strategic advantages of moving before rivals. Bagwell (1995) gives a precise definition of the assumptions behind games 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 the first movers. Thus, when a firm has commitment power, it can play strategically to affect rivals’ choices. In this paper, we follow Bagwell’s (1995) definition and apply it to investment in R&D.

In game terms, a firm has commitment power in R&D when it 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 in R&D: the firm sets outputs and R&D levels simultaneously. Thus, when a firm has commitment power in R&D, it can use R&D to both improve its own productivity levels and to affect the rival’s strategic decisions. When a firm does not have commitment power in R&D, it can still use R&D to improve its own productivity, but it cannot use R&D to affect the rival’s strategic choices.

In this sense, we assume that only the home firm has commitment power in R&D, i.e.: the home firms is the R&D leader and the foreign firms is the R&D follower\(^{11}\). The timing of the multinational game is then the following.

---

\(^{11}\)Note then that we do not explain where commitment power in R&D comes from. The standard explanation for the first mover advantages is that a firm is the leader in the industry (von Stackelberg, 1934). Other reasons can be privileged access to financial capital (Cabral et al., 2003), R&D races (Dasgupta and Stiglitz, 1980) or reputation (Kreps and Wilson, 1982). For papers that endogenize the first mover advantage of Stackelberg
In stage 1, the home and the foreign firm decide the mode of entry in the third market: non entry (0), export (E) or multinational (M). In stage 2, the home firm chooses R&D ($k$). In stage 3, the home firm chooses outputs ($q$) while the foreign firm chooses both outputs ($q^*$) and R&D levels ($k^*$).

Due to the first mover advantage in R&D, then, the home firm can affect the output and R&D decisions of the foreign firm. However, and very importantly, given that the foreign firm decides on the mode of entry before the R&D decision of the home firm, the R&D leader advantage of the home firm cannot influence the entry decision of the foreign firm (multinational versus domestic versus non entry)\footnote{In Petit and Sanna-Randaccio (2000) the timing of the game is the following: in the first stage the home and the foreign firm make the entry decision (non entry, export or multinational), in the second stage the home and the foreign firm choose R&D levels, and in the third stage the home and the foreign firm compete in outputs. Therefore, also in Petit and Sanna-Randaccio (2000), R&D cannot affect entry strategies. For models where MNFs have a first mover advantage on the timing of entry see Horstmann and Markusen (1987).}. However, since R&D can affect firms’ productivity level, R&D can also indirectly affect equilibrium market structure. Accordingly, more productive firms can more easily pay for the extra costs of multinational activity due to larger economies of scale. The aim of this set up is then to analyze how asymmetries on commitment power in R&D affect directly firms’ productivity and indirectly multinational activity.

\section{Production Equilibrium}

As usual the game is solved by backward induction. Output expressions are found by solving the first order conditions (FOCs) for outputs. However, since these FOCs depend on market structure, different output expressions apply for the different market structure cases. Accordingly, when both firms are multinationals we have:

\begin{equation}
q_{M,M} = \frac{D + 2\theta k_{M,M} - \theta k^*_{M,M}}{3b} \quad q^*_{M,M} = \frac{D + 2\theta k^*_{M,M} - \theta k_{M,M}}{3b}
\end{equation}

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

Leaders see for example Hamilton and Slutsky (1990).
When both firms are exporters, we obtain:

\[
q_{E,E} = \frac{D-t+2b k_{E,E}-\theta k_{E,E}^*}{3b} \quad q_{E,E}^* = \frac{D-t-2b k_{E,E}^*}{3b}
\]

(4)

If the home firm is an exporter and the foreign firm is a multinational:

\[
q_{E,M} = \frac{D-2t+2b k_{E,M}-\theta k_{E,M}^*}{3b} \quad q_{E,M}^* = \frac{D+2t+2b k_{E,M}^*}{3b}
\]

(5)

If the home firm is a multinational and the foreign firm is an exporter:

\[
q_{M,E} = \frac{D+t+2b k_{M,E}-\theta k_{M,E}^*}{3b} \quad q_{M,E}^* = \frac{D-2t+2b k_{M,E}^*}{3b}
\]

(6)

In turn, if the home firm has a multinational monopoly we get:

\[
q_{M,0} = \frac{D+\theta k_{M,0}}{2b}
\]

(7)

And if the home firm has an exporting monopoly it results:

\[
q_{E,0} = \frac{D-t+\theta k_{E,0}}{2b}
\]

(8)

Obviously, the expressions \(q_{0,M}^*\) and \(q_{0,E}^*\) are exactly the same as \(q_{M,0}\) and \(q_{E,0}\), with \(k_{M,0}\) and \(k_{E,0}\) substituted for \(k_{0,M}^*\) and \(k_{0,E}^*\), respectively.

To derive the R&D expressions, we now use the FOCs for R&D investment. These FOCs, however, depend not only on market structure but also on whether a firm has commitment power in R&D or not. To clarify this it might be helpful to write down the home firm’s FOC for R&D:

\[
\frac{d\Pi_{i,j}}{dk_{i,j}} = \frac{\partial \Pi_{i,j}}{\partial k_{i,j}} + \frac{\partial \Pi_{i,j}}{\partial q_{i,j}^*} \frac{dq_{i,j}^*}{dk_{i,j}} \quad \text{for } i, j \neq 0
\]

(9)

The first and the second terms in right hand side of equation 9 are usually called the non strategic and the strategic motive for R&D, respectively (see
Leahy and Neary, 1997 for this terminology. Two cases are possible related with these two terms. First, when a firm has commitment power in R&D and has a rival firm, the strategic term is non zero, i.e.: R&D investment is strategic, because the firm can affect the rival’s strategic choices (outputs and R&D). This is the case of the home firm in the duopoly cases. Second, when a firm has either no commitment power in R&D or it is a monopolist, the strategic term in equation 9 vanishes, i.e.: R&D investment is non strategic. This is the case of the foreign firm in all duopoly cases and of the home and the foreign firm in the monopoly cases. Summing up, the home firm in the duopoly cases has a FOC such as the one in equation 9. In turn, the foreign firm’s FOC in all market structure cases is the following:

\[
\frac{d\Pi^*_{i,j}}{dk_{i,j}} = \left( \frac{\partial \Pi^*_{i,j}}{\partial k_{i,j}} \right)_{\text{Non strategic motive for R&D}} + \left( \frac{\partial \Pi^*_{i,j}}{\partial q_{i,j}} \right)_{\text{Strategic motive for R&D=0}} \\
= \frac{\partial \Pi^*_{i,j}}{\partial k_{i,j}}, \text{ for } j \neq 0 \text{ and } i = 0, E, M \tag{10}
\]

The same happens for the home firm in the monopoly cases where the home firm’s FOC equals: \( \frac{d\Pi^*_{i,0}}{dk_{i,0}} = \frac{\partial \Pi^*_{i,0}}{\partial k_{i,0}} \). We then have that the foreign firm’s R&D expressions, independently of market structure, always equal:

\[
k^*_i = \frac{\theta}{\gamma} q^*_i, \text{ for } j \neq 0 \text{ and } i = 0, E, M \tag{11}
\]

In turn, R&D expressions for the home firm can take two forms. The first holds in the monopoly market structures where the home firm has a similar R&D expression to that of the foreign firm:

\[
k_{i,0} = \frac{\theta}{\gamma} q_{i,0}, \text{ for } i = E, M \tag{12}
\]

The second holds in the duopoly cases, where R&D investment by the home firm is now:

\[
k_{i,j} = \frac{\theta}{3\gamma} q_{i,j}, \text{ for } i, j \neq 0 \tag{13}
\]

We can then see that in the duopoly cases, the home and the foreign firm have asymmetric incentives to invest in R&D (see equations 11 and 13).

---

\(^{13}\)Note that the whole home firm’s FOC for R&D is: \( \frac{d\Pi}{dk} = \frac{\partial \Pi}{\partial k} + \frac{\partial \Pi}{\partial q} \frac{dq}{dk} + \frac{\partial \Pi}{\partial q} \frac{dq^*}{dk} \). However, from the FOC for outputs we have that \( \frac{\partial \Pi}{\partial q} = 0 \).
Accordingly, differences in commitment power in R&D create endogenous asymmetries between the home and the foreign firm, in terms of marginal costs and therefore productivity (i.e.: competitiveness and size). In particular, the home firm (the R&D leader) over invests by a proportion of \( \frac{4}{3} \) relatively to the foreign firm (the R&D follower)\(^{14} \). As we will see in the next sections, this endogenous asymmetry property of our model is going to have important consequences in the equilibrium market structure.

We can now solve for the explicit output and R&D expressions for the different market structure cases to obtain:

\[
\begin{align*}
q_{M,M} &= \frac{3D(1-\eta)}{b(9-2\eta(7-2\eta))} \\
q_{*_{M,M}} &= \frac{D(3-4\eta)}{b(9-2\eta(7-2\eta))} \\
k_{M,M} &= \frac{4\theta D(1-\eta)}{b\gamma(9-2\eta(7-2\eta))} \\
k_{*_{M,M}} &= \frac{\theta D(3-4\eta)}{b\gamma(9-2\eta(7-2\eta))} \\
q_{E,E} &= \frac{3(D-t)(1-\eta)}{b(9-2\eta(7-2\eta))} \\
q_{*_{E,E}} &= \frac{(D-t)(3-4\eta)}{b(9-2\eta(7-2\eta))} \\
k_{E,E} &= \frac{4\theta (D-t)(1-\eta)}{b\gamma(9-2\eta(7-2\eta))} \\
k_{*_{E,E}} &= \frac{\theta (D-t)(3-4\eta)}{b\gamma(9-2\eta(7-2\eta))} \\
q_{E,M} &= \frac{3((D-t)(1-\eta)-t)}{b(9-2\eta(7-2\eta))} \\
q_{*_{E,M}} &= \frac{D(3-4\eta)+3t}{b(9-2\eta(7-2\eta))} \\
k_{E,M} &= \frac{4\theta ((D-t)(1-\eta)-t)}{b\gamma(9-2\eta(7-2\eta))} \\
k_{*_{E,M}} &= \frac{\theta (D(3-4\eta)+3t)}{b\gamma(9-2\eta(7-2\eta))} \\
\end{align*}
\]

\(^{14}\)This is so because in Cournot competition outputs are strategic substitutes (see Bulow et al. 1985), i.e.: if \( q^* \) increases, \( q \) decreases (and in consequence also the home firm’s profits). But since when \( k \) increases, \( q^* \) decreases, then \( \frac{\partial}{\partial q^*} \frac{dq^*}{dk} = \frac{\theta}{\frac{\partial q^*}{\partial k}} > 0 \), i.e.: the strategic effect of R&D is positive for the home firm.
\[
q_{M,E} = \frac{3(D(1-\eta)+t)}{b(9-2\eta(1-2\eta))}
\]
\[
q_{M,E}^* = \frac{(D-t)(3-4\eta)-3t}{b(9-2\eta(1-2\eta))}
\]
\[
k_{M,E} = \frac{2\theta(1-\eta)+t}{b\gamma(9-2\eta(1-2\eta))}
\]
\[
k_{M,E}^* = \frac{\theta((D-t)(3-4\eta)-3t)}{b\gamma(9-2\eta(1-2\eta))}
\]
\[
q_{M,0} = q_{0,M} = \frac{D}{b(2-\eta)}
\]
\[
k_{M,0} = k_{0,M} = \frac{\theta D}{b\gamma(2-\eta)}
\]
\[
q_{E,0} = q_{0,E} = \frac{D-t}{b(2-\eta)}
\]
\[
k_{E,0} = k_{0,E} = \frac{\theta(D-t)}{b\gamma(2-\eta)}
\]

where, like in Leahy and Neary (1997) the parameter \( \eta \) equals:

\[
\eta = \frac{\theta^2}{\gamma b}
\]

A high \( \eta \) represents a large return on innovative activities, since the cost reducing effect of R&D (\( \theta \)) weighted by market size (1/\( b \)) is large relatively to its cost (\( \gamma \)). The reverse holds for low \( \eta \). Then, \( \eta \) can be thought of as an indicator of the “relative return to R&D” (see Leahy and Neary, 1997 for this terminology). As we will see bellow, the parameter \( \eta \) affects the fierceness (or softness) of competition.

We restrict the parameter space so that trade costs do not forbid exports. If we assume otherwise, our model would be biased for the multinational strategy. It can easily be checked that in order to have trade in all market structure configurations we just need to guarantee that \( q_{M,E}^* > 0 \), or\footnote{This is the situation where a firm is at more competitive disadvantage: an exporter with no commitment power facing a multinational with commitment power. Then, in no other case a firm has so much difficulties to export.}:

\[
\hat{t} < \frac{(3-4\eta)D}{2(3-2\eta)}
\]
\[
0 < \hat{\eta} < \frac{3}{4}
\]
The second equation above also assures that all second order conditions (SOCs) are always satisfied (see appendix)\(^{16}\).

4 R&D and Firm’s Competitiveness

Even with initially symmetric firms, our model can then predict endogenous asymmetries between firms on marginal costs (i.e.: firms with different levels of investment in R&D). As we have mentioned above, what drives this result is asymmetries in commitment power in R&D, which endogenizes productivity asymmetries between the home and the foreign firm.

In this section, we are going to show that the R&D leader (the home firm) tends to produce and invest more in R&D than the R&D follower (the foreign firm). As a result, the home firm also tends to be more competitive and bigger in size than the foreign firm. To see this, note first that the home firm has always a competitiveness and a size advantage over the foreign firm when the two firms have symmetric entry strategies (multinational duopoly and exporting duopoly) or the home firm is a multinational and the foreign firm is an exporter (see appendix):

\[
\begin{align*}
    k_{M,M} &> k_{M,M}^* \text{ and } q_{M,M} > q_{M,M}^* \\
k_{E,E} &> k_{E,E}^* \text{ and } q_{E,E} > q_{E,E}^* \\
k_{M,E} &> k_{M,E}^* \text{ and } q_{M,E} > q_{M,E}^*
\end{align*}
\]  

(17)

Furthermore, even when the home firm is in disadvantage in the entry strategy (i.e.: the home firm is domestic and the foreign firm is multinational, \((E, M)\) market structure), the home firm can even so become more competitive than the foreign firm if trade costs \((t)\) are not very high or the return on R&D \((\eta)\) is not very low:

\[
\begin{align*}
k_{E,M} &> k_{E,M}^* \text{, if } t < \frac{D}{1-4\eta} \text{ and } q_{E,M} > q_{E,M}^* \text{, if } t < \frac{\eta D}{3(3-\eta)}
\end{align*}
\]  

(18)

Accordingly, when trade costs are very high, the R&D leader advantage of the home firm cannot surpass the trade cost advantage of the foreign multinational firm.

\(^{16}\)Note then that the parameter space for the relative return on R&D is in the interval of the empirical estimates of Griliches (1986), 33% to 66%.
More important for our paper, however, is the role of $\eta$. As we have just seen, high return on R&D (high $\eta$) makes the home firm more competitive relatively to the foreign firm, and the contrary low $\eta$. In other words, high $\eta$ makes competition fiercer against the foreign firm, and the reverse for low $\eta$. The reason for this result is that for high $\eta$ the R&D leader (the home firm) can more easily impose the R&D leader advantage on the R&D follower (the foreign firm). As we will see, this asymmetry in the behavior of the home firm and the foreign firm in relation to the parameter $\eta$ will play an important role in the entry strategies of the two firms.

Summing up, due to asymmetries in commitment power in R&D, the home firm and the foreign firm become endogenously asymmetric in marginal costs. In particular, the R&D leader (the home firm) tends to achieve higher competitiveness and size than the R&D follower (foreign firm). This result is particularly interesting since both firms are initially symmetric in marginal costs (i.e.: $c = c^*$).

It is then important to distinguish the first mover advantages in R&D from the first mover advantages in outputs (von Stackelberg, 1934). Like in a standard Stackelberg output leader set up, commitment power in R&D gives leader advantages to a firm that competes with another one that lacks such capability. However, differently from standard output leader models, firms with different levels of commitment power in R&D can become endogenously asymmetric in marginal costs, i.e.: our model endogenizes productivity and, therefore, competitiveness and firm size. Note that this never occurs in standard Stackelberg output models, where we have that the Stackelberg leader produces more than the Stackelberg follower but both have the same marginal costs\(^{17}\). As will see in the next sections, this difference is going to have important implications in terms of the mode of foreign expansion by firms.

5 **Profits and Entry Strategy**

In this section, we derive the profit expressions under the different market structure configurations and perform comparative static exercises in some of the parameters of the model. The profits expressions will be used in the next section to find the solution of the first stage of our game.

\(^{17}\)In this sense, our model also rationalizes the Stackelberg leader advantages. Accordingly, the Stackelberg leader produces more because when for example it moves first in R&D, it achieves lower marginal costs.
We start with the monopoly cases. Since a monopolist is not affected by commitment power in R&D, a monopoly by the home firm is exactly the same as a monopoly by the foreign firm:

\[
\begin{align*}
\Pi_{M,0} & = \Pi_{0,M}^* = \frac{(2-\eta)D^2}{2b(2-\eta)^2} - \rho G \\
\Pi_{E,0} & = \Pi_{0,E}^* = \frac{(2-\eta)(D-t)^2}{2b(2-\eta)^2} - G
\end{align*}
\]

In the duopoly cases, in turn, the home and the foreign firm will have different profit levels, since differences in commitment power in R&D make the two rivals endogenously asymmetric:

\[
\begin{align*}
\Pi_{M,M} & = \frac{(9-8\eta)D^2(1-\eta)^2}{6(9-2\eta)(7-2\eta)^2} - \rho G \\
\Pi_{M,M}^* & = \frac{(2-\eta)D^2(3-4\eta)^2}{2b(9-2\eta)(7-2\eta)^2} - \rho G \\
\Pi_{E,E} & = \frac{(9-8\eta)(D-t)^2(1-\eta)^2}{6(9-2\eta)(7-2\eta)^2} - G \\
\Pi_{E,E}^* & = \frac{(2-\eta)(D-t)^2(3-4\eta)^2}{2b(9-2\eta)(7-2\eta)^2} - G \\
\Pi_{E,M} & = \frac{(9-8\eta)((D-t)(1-\eta)+t)^2}{6(9-2\eta)(7-2\eta)^2} - G \\
\Pi_{E,M}^* & = \frac{(2-\eta)((3-4\eta)D+3t)^2}{2b(9-2\eta)(7-2\eta)^2} - \rho G
\end{align*}
\]

To derive the entry equilibrium, which will be done in the next section, we also need to compute the firms’ preferences over different market structure configurations. In fact, as shown in figure 1, the Nash solution of the entry stage is a three-by-three matrix with three strategic choices (non entry, export and multinational) and two players (the home and the foreign firm). Thus,
we have to compare for the home firm $\Pi_{M,M}$ with $\Pi_{E,M}$; $\Pi_{M,E}$ with $\Pi_{E,E}$; and $\Pi_{M,0}$ with $\Pi_{E,0}$ (and for the foreign firm $\Pi^*_M$, with $\Pi^*_E$, $\Pi^*_E$ with $\Pi^*_M$, and $\Pi^*_0$, with $\Pi^*_0$):

$$\Pi_{M,M} - \Pi_{E,M} = (9 - 8\eta) \frac{t^{2D(2-\eta)(3-\eta)-(4-\eta)(4-\eta)}}{b(9-2\eta(7-2\eta))^2} - G(\rho - 1)$$

$$\Pi_{M,E} - \Pi_{E,E} = (9 - 8\eta) \frac{2D(2-\eta)(3-\eta)+t(2-\eta)}{b(9-2\eta(7-2\eta))^2} - G(\rho - 1)$$

$$\Pi_{M,0} - \Pi_{E,0} = \Pi^*_0 - \Pi^*_E = \frac{2D-t}{2(2-\eta)} - G(\rho - 1)$$

$$\Pi^*_{M,M} - \Pi^*_E = 2(2 - \eta) \frac{(D-t)(9-4\eta(3-\eta))-2D\eta(3-2\eta)}{b(9-2\eta(7-2\eta))^2} - G(\rho - 1)$$

$$\Pi^*_E - \Pi^*_E = 2(2 - \eta) \frac{(9-2\eta(9-4\eta)+2\eta(3-2\eta)}{b(9-2\eta(7-2\eta))^2} - G(\rho - 1)$$ (21)

We are now in conditions to analyze the role of the three central parameters in the model ($G$, $t$, and $\eta$) on the firms’ entry decision. Plant specific fixed costs ($G$) and transport costs ($t$) relate with the size effect, since they affect the size of the firms, i.e.: low $G$ increases profits and low $t$ allows the firms to sell more (this is more evident for multinational firms since $t_M = 0$). The return on R&D ($\eta$), in turn refers to both the size and the technological effect. The size effect arises, since higher relative return on R&D allows firms to reduce more the marginal costs. The technological effect enters, because as we have seen in the previous section, the R&D leader and the R&D follower react differently to different levels of $\eta$.

In what refers to $G$, as it is evident from equations 19 to 21, for both the home and the foreign firm, the multinational strategy is penalized for high $G$, and the reverse for the export strategy. In view of that, higher plant specific fixed costs make it less attractive to choose the multinational strategy in relation to the export strategy.
In terms of \( t \), and as shown in appendix, for both the home and the foreign firm, the export strategy is penalized for high \( t \), and the contrary for the multinational strategy:

\[
\frac{d \Pi_{E,j}}{dt} < 0 \quad \text{and} \quad \frac{d \Pi_{i,E}}{dt} < 0 \quad \text{with} \quad i, j = 0, E, M \\
\frac{d \Pi_{M,j}}{dt} > 0 \quad \text{and} \quad \frac{d \Pi_{i,M}}{dt} > 0 \quad \text{with} \quad i, j = 0, E, M \\
\frac{d \Pi_{M(j-E),j}}{dt} > 0 \quad \text{and} \quad \frac{d \Pi_{i,M-E}}{dt} > 0 \quad \text{with} \quad i, j = 0, E, M
\] (22)

Accordingly, higher trade costs make it more profitable for firms to be closer to consumers in order to save in trade costs (i.e.: multinational strategy). We then have that, for both the home firm and the foreign firm, the export strategy is penalized for low \( G \) and high \( t \), and the contrary for the multinational strategy. This is basically the proximity-concentration trade-off (see Horstmann and Markusen, 1992). Then in what concerns \( G \) and \( t \), our model replicates the results in the FDI literature. The novelty comes when we look to the parameter \( \eta \), which as we have discussed previously, captures the technological effect.

Turning then to the role of \( \eta \) on the firms’ mode of foreign expansion, we have the following. In the monopoly cases, for both the home and the foreign firm, we obtain what we would expect. In particular, an increase in \( \eta \) represents an increase in profits and a promotion of the multinational strategy relatively to the exporting strategy (see appendix). Accordingly, since for every dollar invested a firm gets much more in return when R&D investment is more efficient, then profits increase and it is easier to pay the extra plant specific fixed costs that are needed under the multinational strategy.

The same, however, does not happen in the duopoly cases. In fact, while in the monopoly market structures an increase in the return of R&D is good for profitability and for the multinational strategy, in the duopoly market structures this depends on the type of firm we are looking at, i.e.: if the firm is a R&D leader or a R&D follower. In particular, while the R&D leader (home firm) tends to have higher profits and to choose the multinational strategy for higher \( \eta \), the opposite occurs for the R&D follower (foreign firm). This is an interesting result, because as discussed above, we expect that higher relative return on R&D contributes positively for profits under all modes of foreign expansion (export and multinational) and to make the multinational option relatively more attractive than the exporting strategy.
To be more precise, we have that for the duopoly cases \((M, M)\), \((E, E)\) and \((M, E)\), while for the foreign firm (the R&D follower) an increase in \(\eta\) results in a reduction of profits, for the home firm (the R&D leader) this represents an increase in profits. Only in the \((E, M)\) market structure the opposite might occur (i.e.: an increase in \(\eta\) might benefit the foreign firm at same time it penalizes the home firm) if \(\eta\) is sufficiently low, i.e.: if R&D competition against the R&D follower is not very fierce. To prove this, note that the following relations hold (see appendix):

\[
\frac{d\Pi_{M,M}}{d\eta} > 0, \quad \frac{d\Pi_{E,E}}{d\eta} > 0 \quad \text{and} \quad \frac{d\Pi_{M,E}}{d\eta} > 0
\]
\[
\frac{d\Pi_{E,M}}{d\eta} > 0 \quad \text{for high} \ \eta, \quad \frac{d\Pi_{E,M}}{d\eta} < 0 \quad \text{for low} \ \eta
\]
\[
\frac{d\Pi_{M,M}}{d\eta} < 0, \quad \frac{d\Pi^{*}_{E,E}}{d\eta} < 0 \quad \text{and} \quad \frac{d\Pi^{*}_{M,E}}{d\eta} < 0
\]
\[
\frac{d\Pi^{*}_{E,M}}{d\eta} < 0 \quad \text{for high} \ \eta, \quad \frac{d\Pi^{*}_{E,M}}{d\eta} > 0 \quad \text{for low} \ \eta
\]  

(23)

Besides, in the duopoly cases, an increase in \(\eta\) (i.e.: fiercer R&D competition against the R&D follower) always promotes the home firm to choose the multinational strategy relatively to the exporting one. For the foreign firm, the opposite occurs, except when \(\eta\) is sufficiently low (see appendix):

\[
\frac{d\Pi^{*}_{M,M}}{d\eta} < 0 \quad \text{for high} \ \eta, \quad \frac{d\Pi^{*}_{M,M}}{d\eta} > 0 \quad \text{for low} \ \eta
\]
\[
\frac{d\Pi_{E,E}}{d\eta} > 0 \quad \text{for} \ i, j = E, M\]
\[
\frac{d\Pi^{*}_{M-E,E}}{d\eta} < 0 \quad \text{for high} \ \eta, \quad \frac{d\Pi^{*}_{M-M-E}}{d\eta} > 0 \quad \text{for low} \ \eta, \ \text{with} \ i, j = E, M
\]  

(24)

The reason for the results in equations 23 and 24 is that for high \(\eta\), the R&D leader (the home firm) can more easily impose the R&D leader advantage to the R&D follower (the foreign firm). In other words, a high \(\eta\) magnifies the productivity differences between the R&D leader and the R&D follower (i.e.: high \(\eta\) makes R&D competition against the R&D follower tougher). As a result, profits by the home firm increase and it is also more profitable for the home firm to choose the multinational strategy, and the opposite for the foreign firm.

We then have that for high \(\eta\) the technological effect becomes more important for the benefit of firm with higher commitment power. In addition, and as a consequence of the former, this firm can more easily become a multinational. In this sense, this result corroborates the empirical evidence on the importance of the technological effect for FDI (see Doms and Jensen, 1998;
Bernard et al., 2004; Criscuolo et al., 2004; Markusen and Maskus, 2004 and Girma and Görg, 2006.)

Summing up, higher $t$ and lower $G$ promote the multinational strategy over the export strategy. In turn, for the R&D leader, higher $\eta$ tends to promote international activity (export and multinational) and to favor the multinational strategy over the domestic strategy. The reverse happens for the R&D follower. We can then see that while $G$ and $t$ work symmetrically for the home and the foreign firm, $\eta$ has asymmetric effects on the two firms. The reason for the asymmetry in behavior of the home firm and the foreign firm in relation to $\eta$ is asymmetries in commitment power in R&D. Accordingly, the R&D leader (home firm) and the R&D follower (foreign firm) react differently to different levels of the relative return on R&D.

6 Equilibrium Market Structure

As shown by Horstmann and Markusen (1992), in order to derive the equilibrium market structure of the FDI game above, we need to use the relations in the entry profit matrix (figure 1) and equations 19 to 21. From here, we can construct the entry equilibrium in the $(G, t)$ space as shown in figures 2 and 3. Figure 2 arises for high values of $\eta$ (i.e.: fierce R&D competition), while figure 3 arises for low $\eta$ (i.e.: soft R&D competition)\(^\text{18}\). In particular, figure 2 is constructed with $D = 20$, $b = 1$, $\rho = 2$ and $\eta = 0.2$; and figure 3 is obtained with $D = 20$, $b = 1$, $\rho = 2$ and $\eta = 0.1$.

Due to the modeling strategy adopted, it can be noticed from figures 2 and 3 that the solution of the entry stage in our model shares some similarities with other FDI models, such as Horstmann and Markusen (1992) and Petit and Sanna-Randaccio (2000). In fact, we can see now more clearly that, as discussed already in the previous section, our model also displays the proximity-concentration trade-off: for high trade costs and low plant specific fixed costs the multinational strategy is preferred; while for high plant specific fixed costs and low trade costs the exporting strategy is favored.

There are also some differences. For instances, our model predicts some

\(^{18}\)Figures 2 and 3 depict the following profit curves (colors indicated in parenthesis): $\Pi_{M,M}$ and $\Pi_{M,M}^*$ (black), $\Pi_{E,E}$ and $\Pi_{E,E}^*$ (blue), $\Pi_{E,M}$ and $\Pi_{E,M}^*$ (brown), $\Pi_{M,E}$ and $\Pi_{M,E}^*$ (cyan), $\Pi_{M,0}$ (orange), $\Pi_{E,0}$ (dark green), $\Pi_{M,M} - \Pi_{E,M}$ and $\Pi_{M,M}^* - \Pi_{M,E}^*$ (magenta), $\Pi_{M,E} - \Pi_{E,E}$ and $\Pi_{E,M} - \Pi_{E,E}^*$ (light green), $\Pi_{M,0} - \Pi_{E,0}$ (red). The home firm’s profits curves are represented by solid lines while the foreign ones by dash lines.
market structure equilibriums not present in either Horstmann and Markusen (1992) or Petit and Sanna-Randaccio (2000). Accordingly, Horstmann and Markusen (1992) predict the following market structures in equilibrium: 

\((0, 0)\), \((E, 0)(0, E)\), \((E, E)\), \((M, 0)(0, M)\), \((M, M)\) and \((E, E)(M, 0)(0, M)\); while Petit and Sanna-Randaccio (2000) in addition also have the \((M, E)(E, M)\) market structure equilibrium and for some parameter values there is no Nash equilibrium. In our paper, besides the market structure equilibriums previously mentioned, we can also have the following ones: \((E, 0)\), \((M, 0)\), \((M, E)\), 

\((E, E)(M, 0)\) and \((E, M)(M, 0)\). Then, our model predicts a richer set of market structure equilibriums.

We have therefore to understand the emergence of these new equilibriums. Look first at the following market structure equilibriums: \((E, 0)\), \((M, 0)\) and \((M, E)\). In our paper, and contrary to what occurs in Horstmann and Markusen (1992) and Petit and Sanna-Randaccio (2000), the previous mentioned equilibriums are obtained as single Nash equilibriums. Accordingly, in Horstmann and Markusen (1992) and Petit and Sanna-Randaccio (2000), the \((E, 0)\), \((M, 0)\) and \((M, E)\) market structures only arise in mixed strategies.
equilibriums together with the \((0, E), (0, M)\) and \((E, M)\) market structures, respectively. We can then see that asymmetries on commitment power in R&D reduce the indeterminacy of the market structure equilibrium.

Other way to look at this is to argue that in Horstmann and Markusen (1992) and in Petit and Sanna-Randaccio (2000) is not possible to predict which of the asymmetric market structures arise in equilibrium, i.e.: it can either be \((E, 0)\) or \((0, E)\), \((M, 0)\) or \((0, M)\), \((M, E)\) or \((E, M)\). However, as we know from the FDI data, international FDI patterns are very asymmetric (see Markusen, 2002). One way found in the FDI literature to predict which asymmetric FDI patterns will arise in equilibrium is to introduce some sort of asymmetry, such as for example asymmetries in market size (Pontes, 2001) or international differences in factor endowments (Markusen and Venables, 1998). In this paper, we are able to do this by introducing asymmetries in commitment power in R&D. However, the type of asymmetry is specially interesting because it allows us to endogenize productivity asymmetries between firms, which in turn support asymmetric entry strategies.

We can see these effects more clearly at work in the \((E, 0)\), \((M, 0)\) and
market structures equilibriums. In fact, and depending on market conditions ($G$ and $t$), it is possible that only the more competitive firm (the R&D leader) can enter the market as an exporter or a multinational, while the less competitive firm (the R&D follower) just stays out of the market (($E, 0)$ and ($M, 0)$ market structures equilibriums). Other alternative is that the former becomes a multinational while the latter becomes an exporter (($M, E)$ market structure equilibrium). Then, similarly to Helpman et al. (2004), also in our paper productivity asymmetries between firms can separate multinationals from exporters and non entrants. The difference relative to Helpman et al. (2004) is that in the present paper asymmetries between firms are endogenous, while in Helpman et al. (2004) they are exogenous.

To see the role of asymmetries between firms on the market structure equilibrium, we make two vertical cuts in figure 2 for low and high trade costs. The resulting pictures are shown in figures 4 and 5. Figure 4 emerges for the vertical cut in figure 2 made for low $t$, while figure 5 arises for the vertical cut made in figure 2 for high $t$.

These two figures show more clearly that the decision between multinational, export and non entry depends not only in the proximity-concentration trade-off but also on the R&D leader-follower relationship (i.e.: the technological effect). A lower level of $G$ promotes symmetric duopoly equilibriums (($M, M)$ and ($E, E$)). In turn, low-medium $G$ encourages a change from duopoly equilibriums to multinational or exporting monopolies equilibriums by the R&D leader (home firm) or to asymmetric duopoly equilibriums with the home firm being a multinational and the foreign firm being an exporter (($M, 0), (E, 0)$ and ($M, E$), respectively). Medium-high $G$ triggers the emergence of multinational or exporting monopolies by either the home or the foreign firm (($M, 0)(0, M)$ and $(E, 0)(0, E)$). Finally, very high $G$ naturally promotes non entry.

In other words, the proximity-concentration trade-off arises since in both figures 4 and 5 as $G$ decreases we go from non entry to export and only then to multinational. However, in figure 4, as $G$ decreases we pass from the market structure $(E, 0)(0, E)$ to $(E, 0)$ and from $(E, E)$ to $(M, E)$. In turn, in figure 5, as $G$ decreases we move from the market structure $(E, 0)(0, E)$ to $(E, 0)$ and from $(M, 0)(0, M)$ to $(M, 0)$. Therefore, the R&D leader (the firm which tends to have higher competitiveness and size) can gain advantage in the entry strategy over the R&D follower as $G$ decreases.

We are now just left to understand the following market structure equilibriums not present in Horstmann and Markusen (1992) and Petit and Sanna-
Figure 4: Multinational, Domestic, Non Entry: Low Trade Costs

Figure 5: Multinational, Domestic, Non Entry: High Trade Costs
Randaccio (2000): \((E, E)(M, 0)\) and \((E, M)(M, 0)\). Note that these equilibriums only arise for low \(\eta\), i.e.: when R&D competition against the R&D follower is not very fierce. Not surprisingly, the foreign firm can only aspire to be a multinational against a domestic home firm \((E, M)(M, 0)\) equilibrium) for low \(\eta\). This means that a multinational firm that has no commitment power in R&D finds it difficult to compete successfully with a domestic firm that has commitment power in R&D, unless the return on R&D is very low.

In fact, as we have already discussed before, for low return on R&D (figure 3) the R&D follower (the foreign firm) can more easily face the R&D leader. In turn, for high return on R&D (i.e.: high \(\eta\), figure 2), the R&D leader (the home firm) can more easily impose the R&D leader advantage. This can more easily be seen by noticing that the \((E, 0)\), \((M, 0)\) and \((M, E)\) market structures (where the R&D leader has a clear advantage over the R&D follower) are more likely to arise for high \(\eta\) than for low \(\eta\), i.e.: the areas for these market structure equilibriums are larger in the former. In other words, the technological effect can potentially be more important than the size effect, if the relative return on R&D is large and a firm is a R&D leader.

In our view, other important thing to notice is that while the proximity-concentration trade-off works symmetrically for both the home and the foreign firm, the “technological” effect (which runs through \(\eta\)) affects the two firms asymmetrically: high return on R&D (high \(\eta\)) favors the R&D leader (the home firm) against the R&D follower (the foreign firm), while low return on R&D (low \(\eta\)) favors the R&D follower against the R&D leader. In this sense, this paper then introduces a new FDI determinant apart from the proximity-concentration trade-off: international technological competition.

Summing up, relatively to other horizontal FDI models our model features four main differences. First, we endogenize productivity differences between firms via differences in commitment power in R&D. Second, we are able to predict single equilibriums for asymmetric market structure configurations \(((E, 0), (M, 0)\) and \((M, E))\). Third, international R&D competition can affect asymmetrically different firms, depending on their commitment power in R&D. Fourth, besides size effects and the proximity concentration trade-off, we introduce the technological effect and international technological competition as determinants of FDI. What drives these results are asymmetries in commitment power in R&D. Accordingly, a R&D leader can become more productive (i.e.: larger in size and more competitive), because it can affect the R&D decisions of the rival. As a result, the R&D leader can also ex-
plore larger economies of scale in multinational activity, especially when the relative return on R&D is high. In this sense, when compared with a R&D follower, a R&D leader finds easy to pay for the extra costs of multinational activity.

7 Conclusion

In this paper, we have studied the relation between FDI, R&D and endogenous productivity asymmetries between firms. Productivity asymmetries arise as a result of differences in commitment power in R&D. In this way, we show that the R&D leader tends to invest more in R&D, and therefore to have lower marginal costs, than the R&D follower. In other words, the R&D leader is more productive (i.e.: more competitive and larger in size) than the R&D follower. The productivity advantage makes it easier for the R&D leader to choose the multinational strategy. Accordingly by being bigger more productive, the R&D leader is able to explore larger economies of scale in multinational activity.

In addition, due to the modeling structure adopted (Horstmann and Markusen, 1992), we also obtain the proximity-concentration trade-off. In other words, a high trade costs promotes the multinational strategy and a higher plant specific fixed costs promotes the exporting strategy. In this sense, multinational firms tend to be bigger in size, because by being closer to consumers (and therefore paying lower trade costs) can achieve higher sales, i.e.: the size effect.

The novelty in our paper, then, comes from the introduction of a technological effect, which arises from firms having differences commitment power in R&D. In fact, as we have seen, asymmetries in commitment power in R&D make investment on R&D to have asymmetric effects on the R&D leader and on the R&D follower. In particular, while higher return on R&D favors the R&D leader over the R&D follower, low return on R&D in turn mitigates the R&D leader advantages of the R&D leader. In addition, higher return on R&D promotes the R&D leader to become a multinational while it promotes the R&D follower to become an exporter. What this means is that although the proximity-concentration trade-off affects all firms symmetrically, the “technological” effect can affect firms asymmetrically.

There are several issues that are disregarded in our paper. First we do not consider the question of the location of R&D (see for example Ekholm
and Hakkala, 2007). Second, we do not take into account the welfare policies directed either to attract FDI or to promote R&D (see Sanna-Randaccio, 2002). Also, our framework should be extended to a more general context (as in Helpman et al., 2004). Future work should aim at incorporating these issues in the model introduced here.

A Appendix

Second Order Conditions for R&D  The SOC for the home firm in all the duopoly cases is:

$$\frac{d^2\Pi_{i,j}}{dk_{i,j}^2} = -\frac{\gamma (9-8\eta)}{9} < 0 \quad \text{for } i, j \neq 0$$  (25)

The SOC for the foreign firm in all the duopoly cases is in turn:

$$\frac{d^2\Pi_{i,j}}{dk_{i,j}^2} = -\frac{(3-2\eta)}{3} < 0 \quad \text{for } i, j \neq 0$$  (26)

Finally, in the monopoly cases, the SOC is the same for both the home and the foreign firm:

$$\frac{d^2\Pi_{i,j}}{dk_{i,j}^2} = \frac{d^2\Pi_{i,j}}{dk_{i,j}^2} = -\frac{\gamma (2-\eta)}{2} < 0 \quad \text{for } i \text{ or } j = 0$$  (27)

Then, the most restricted SOC is $0 < \eta < \frac{9}{8}$.

Proof of Proposition 1

$$k_{M,M} - k_{M,M}^* = \frac{\theta D}{b\gamma (9-2\eta(7-2\eta))} > 0$$
$$k_{E,E} - k_{E,E}^* = \frac{\theta (D-t)}{b\gamma (9-2\eta(7-2\eta))} > 0$$
$$k_{M,E} - k_{M,E}^* = \frac{\theta D + t (10-4\eta)}{b\gamma (9-2\eta(7-2\eta))} > 0$$
$$q_{M,M} - q_{M,M}^* = \frac{\eta D}{b(9-2\eta(7-2\eta))} > 0$$
$$q_{E,E} - q_{E,E}^* = \frac{\eta (D-t)}{b(9-2\eta(7-2\eta))} > 0$$
$$q_{M,E} - q_{M,E}^* = \frac{D\eta + t (9-4\eta)}{b(9-2\eta(7-2\eta))} > 0$$  (28)

$$k_{E,M} - k_{E,M}^* = \frac{\theta (D-t)(11-4\eta)}{b\gamma (9-2\eta(7-2\eta))} > 0 \text{ iff } t < \frac{D}{11-4\eta}$$
$$q_{E,M} - q_{E,M}^* = \frac{D\eta + t (9-3\eta)}{b(9-2\eta(7-2\eta))} > 0 \text{ iff } t < \frac{D\eta}{3(3-\eta)}$$  (29)
Proof of Proposition 2

Profits versus trade costs

For multinationals:

\[
\frac{d\Pi_{M,0}}{dt} = \frac{d\Pi_{M,M}}{dt} = \frac{d\Pi_{E,M}}{dt} = 0
\]

\[
\frac{d\Pi_{M,0}}{dt} = \frac{2(9-8\eta)(D(1-\eta)+t)}{b(9-2\eta(7-2\eta))^2} > 0
\]

\[
\frac{d\Pi_{E,M}}{dt} = \frac{3(2-\eta)(D(3-4\eta)+3t)}{b(9-2\eta(7-2\eta))^2} > 0
\]

For exporters:

\[
\frac{d\Pi_{E,0}}{dt} = -\frac{D-t}{(2-\eta)b} < 0
\]

\[
\frac{d\Pi_{E,E}}{dt} = -\frac{2(9-8\eta)(D-t)(1-\eta)^2}{b(9-2\eta(7-2\eta))^2} < 0
\]

\[
\frac{d\Pi_{E,E}}{dt} = -\frac{2(9-8\eta)(D-t)(1-\eta-t)(2-\eta)}{b(9-2\eta(7-2\eta))^2} < 0
\]

\[
\frac{d\Pi_{M,E}}{dt} = -\frac{(2-\eta)/(D-t)(3-4\eta)}{b(9-2\eta(7-2\eta))^2} < 0
\]

\[
\frac{d\Pi_{M,E}}{dt} = -\frac{2(2-\eta)((D-t)(3-4\eta)-(1-\eta)(3-2\eta))}{b(9-2\eta(7-2\eta))^2} < 0
\]

For multinational versus exporting strategy:

\[
\frac{d(\Pi_{M,0}-\Pi_{E,0})}{dt} = \frac{2(9-8\eta)(D(2-\eta)(3-\eta)-t(4-\eta)(4-\eta)))}{b(9-2\eta(7-2\eta))^2} > 0
\]

\[
\frac{d(\Pi_{M,E}-\Pi_{E,E})}{dt} = \frac{2(9-8\eta)(D(2-\eta)(3-\eta)+t\eta(2-\eta))}{b(9-2\eta(7-2\eta))^2} > 0
\]

\[
\frac{d(\Pi_{M,0}-\Pi_{E,0})}{dt} = \frac{D-t}{(2-\eta)b} > 0
\]

\[
\frac{d(\Pi_{M,M}-\Pi_{E,M})}{dt} = \frac{2(2-\eta)(D(9-2\eta(9-4\eta)-2t(9-4\eta)(3-2\eta)))}{b(9-2\eta(7-2\eta))^2} > 0
\]

\[
\frac{d(\Pi_{E,M}-\Pi_{E,E})}{dt} = \frac{2(2-\eta)(D(9-2\eta(9-4\eta)+4t(3-2\eta))}{b(9-14\eta+4\eta^2)^2} > 0
\]

Profits versus Return on R&D

For the monopoly cases:

\[
\frac{d\Pi_{M,0}}{d\eta} = \frac{D^2}{4(2-\eta)^2b} > 0
\]

\[
\frac{d\Pi_{E,0}}{d\eta} = \frac{(D-t)^2}{2(2-\eta)^2b} > 0
\]
For the home firm in the duopoly cases:

\[
\frac{d\Pi_{M,M}}{d\eta} = \frac{D^2(1-\eta)(9-4\eta(5-\eta(7-4\eta)))}{b(9-2\eta(7-2\eta))^3} > 0
\]

\[
\frac{d\Pi_{E,E}}{d\eta} = \frac{2(D-t)^2(1-\eta)(9-4\eta(5-\eta(7-4\eta)))}{b(9-2\eta(7-2\eta))^3} > 0
\]

\[
\frac{d\Pi_{M,E}}{d\eta} = \frac{(D(1-\eta)+t)(D(9-2\eta(20-4\eta(7-4\eta)))+t(90-16\eta(8-3\eta)))}{b(9-2\eta(7-2\eta))^3} > 0
\]

\[
\frac{d\Pi_{E,M}}{d\eta} = \frac{2((D-t)(1-\eta)-t)(D(9-4\eta(5-\eta(7-4\eta)))-t(99-4\eta(37-\eta(19-4\eta)))}{b(9-2\eta(7-2\eta))^3} \geq 0
\]

< 0 for low \(\eta\) and > 0 for high \(\eta\) \hfill (34)

For the foreign firm in the duopoly cases:

\[
\frac{d\Pi_{M,M}^*}{d\eta} = -\frac{D^2(3-4\eta)(3+2\eta(15-2\eta(11-4\eta)))}{4b(9-2\eta(7-2\eta))^3} < 0
\]

\[
\frac{d\Pi_{E,E}^*}{d\eta} = -\frac{(D-t)^2(3-4\eta)(3+2\eta(15-2\eta(11-4\eta)))}{2b(9-2\eta(7-2\eta))^3} < 0
\]

\[
\frac{d\Pi_{M,E}^*}{d\eta} = -\frac{(D(3-4\eta)+t)(D(3+2\eta(30-\eta(44-16\eta)))+t(138-\eta(168-\eta(80-16\eta)))}{2b(9-2\eta(7-2\eta))^3} < 0
\]

\[
\frac{d\Pi_{E,M}^*}{d\eta} = -\frac{(D(3-4\eta)+3t)(D(3+2\eta(15-2\eta(11-4\eta)))-t(141-2\eta(69-18\eta)))}{4b(9-2\eta(7-2\eta))^3} \geq 0
\]

> 0 for low \(\eta\) and < 0 for high \(\eta\) \hfill (35)

For the home firm, multinational \emph{versus} exporting strategy:

\[
\frac{d(\Pi_{M,M}-\Pi_{E,M})}{d\eta} = 2t\frac{D(117-4\eta(74-\eta(75-2\eta(19-4\eta)))-t(198-\eta(395-4\eta(75-\eta(27-4\eta))))}{b(9-2\eta(7-2\eta))^3} > 0
\]

\[
\frac{d(\Pi_{M,E}-\Pi_{E,E})}{d\eta} = 2t\frac{D(117-4\eta(74-\eta(75-2\eta(19-4\eta)))+t(81-\eta(99-4\eta^2(11-4\eta))}{b(9-2\eta(7-2\eta))^3} > 0
\]

\[
\frac{d(\Pi_{M,E}-\Pi_{E,E})}{d\eta} = t\frac{2D-t}{2(2-\eta)^2}b > 0
\] \hfill (36)

For the foreign firm, multinational \emph{versus} exporting strategy:

\[
\frac{d(\Pi_{M,M}^*-\Pi_{E,M}^*)}{d\eta} = 2t\frac{D(99-2\eta(153-2\eta(81-8\eta(5-\eta)))-t(207-2\eta(195-4\eta(36-\eta(13-2\eta))))}{b(9-2\eta(7-2\eta))^3} \leq 0
\]

\[
\frac{d(\Pi_{E,E}^*-\Pi_{E,E}^*)}{d\eta} = 2t\frac{D(99-2\eta(153-2\eta(81-8\eta(5-\eta)))+t(27-\eta(21+\eta(9-2\eta(7-2\eta)))))}{b(9-2\eta(7-2\eta))^3} \leq 0
\]

> 0 for low \(\eta\) and < 0 for high \(\eta\) \hfill (37)
References


