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ABSTRACT: We analyze a two-country model of Foreign Direct Investment (FDI). Two firms, each of which is originally situated in only one of the two countries, first decide whether to build a plant in the foreign country. Then, they decide whether to relocate R&D activities. Finally, they engage in product-market competition.

Our main points are: first, FDI liberalization causes a relocation of R&D activities if intrafirm communication is sufficiently well developed, external spillovers are substantial, competition is not too strong and foreign markets are not too small. Second, such a relocation of R&D activities will usually nevertheless increase domestic welfare since it only occurs if intrafirm communication is well developed and therefore knowledge generated and obtained abroad flows back to the domestic country. Third, the potential of R&D offshoring makes FDI itself more likely. Fourth, when countries are asymmetric, the small-country firm is more likely to offshore its R&D activities into the large country than conversely.

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1 Introduction

This paper provides a framework for analyzing the determinants of multinational firms' choices of locations for production and R&D simultaneously. Our analysis is motivated by a set of stylized facts on the R&D activities of multinational firms:

Stylized Fact 1 *Most of the private-sector R&D is done by multinational firms.*

According to the *World Investment Report* (UNCTAD 2005), global business R&D expenditure in 2002 amounts to \$450 billion, of which at least two thirds are carried out by multinationals. Having thus established the importance of multinational R&D activities, we turn to facts concerning the location of these activities.

Stylized Fact 2 *R&D activities are highly concentrated geographically.*

In 2002, more than four fifths of global R&D were concentrated in ten countries (UNCTAD 2005). While this statement refers to all R&D activities, it applies in much the same way to those R&D activities that are carried out offshore by multinational firms, that is, in countries where the headquarter is not located.

Stylized Fact 3 *The R&D activities of foreign affiliates of multinational firms are highly concentrated geographically.*

For instance, in a survey of the world's largest R&D spenders reported in UNCTAD (2005), the largest number of firms (58.8%) name the United States as a location of foreign R&D. The next in line are: United Kingdom (47.1%), China (35.5%), France (35.3%), Japan (29.4%), India (25%), Canada (19.1%), Germany (19.1%).

Importantly, R&D offshoring is gaining pace.

Stylized Fact 4 *Multinationals increasingly move their R&D offshore, that is, away from the headquarter locations.*

The global R&D expenditure of foreign affiliates amounted to \$30 billion in 1993 and \$67 billion in 2002 (UNCTAD 2005). Thus while the share of foreign affiliates in total business R&D is still not very high, it is increasing rapidly.¹ This mirrors a broader pattern concerning international service outsourcing. While the share of business services produced abroad is still very low, it has grown substantially recently (Amiti and Wei 2004).

There is also some agreement about the kinds of location where the R&D activities of multinational firms concentrate (Belderbos et al. 2005).

Stylized Fact 5 *R&D by foreign affiliates is attracted particularly*
(i) to large markets and markets with high per capita income;
(ii) to locations where the firms already have manufacturing and sales activities;
(iii) to countries with large technological know-how.

This statement summarizes a large empirical literature.² Several observations illustrate the role of market size and per-capita income (i). First, many multinationals moved their R&D activities to Europe in the late nineteen eighties when the possibility of the single large European market became evident (Caves 1997). Second, similarly, as developing countries such as China and India have recently grown rapidly, so has their share of foreign affiliate R&D (UNCTAD 2005). Third, some smaller countries like Sweden have experienced a more dramatic outflow of R&D activities when their firms engaged in FDI (Caves 1997).

Part (ii) of the statement reflects what used to be the main motive for affiliate R&D, namely the need to adapt products to local demand. Even

¹The internationalization of R&D has also been documented elsewhere (Caves 1996, ch. 7, Florida 1997, Belderbos 2001, 2003, Kuemmerle 1999, von Zedtwitz and Gassmann 2002).

²See, for example, Zejan (1990), Belderbos (2001, 2003).

when the knowledge generated by offshore R&D is used globally, however, this activity is likely to be complementary to horizontal FDI, as research and development activities quite clearly benefit from close spatial interactions with the production process.

Part (iii) of the statement reflects the fact that firms are increasingly using knowledge generated in their international subsidiaries as an input to home-country production. Thus, foreign R&D is often accompanied by technology sourcing, or reverse technology transfer, as Blomström and Kokko (1996) put it: The multinationals benefit from R&D spillovers from local firms which they then use to improve their knowledge base at home.³ It is often argued that technology sourcing played a role for the location decisions of Japanese firms in the U.S. (Kogut and Chang 1991). More generally, the importance of technology sourcing has been documented in many empirical papers.⁴

The growing empirical importance of the phenomenon of R&D offshoring notwithstanding, there is little theoretical analysis of R&D location decisions and, specifically, of technology sourcing. Natural questions are:

1. Under which circumstances do R&D relocation and technology sourcing arise?
2. What are typical characteristics of R&D host countries?
3. How are multinational firms' choices of production locations influenced by considerations concerning R&D locations?
4. What are the welfare effects of R&D offshoring?

³Earlier literature deals with technology transfer through multinational corporations to host countries and with the possible effects on these countries (e.g. Findlay 1978, Mansfield and Romeo 1980, Das 1987, Blomström and Kokko 1996).

⁴Relevant studies include: Cantwell and Hodson (1991), Håkanson and Nobel (1993), Neven and Siotis (1993), OECD (1994), Baily and Gersbach (1995), Fors and Zejan (1996); Almeida (1996), Florida (1997), Kuemmerle (1997), Branstetter (2000) and Frost (2001), Griffith et al. (2003).

In this paper, we analyze these issues in a simple strategic model of locational choice and R&D decisions of multinationals that emphasizes internal and external knowledge flows in multinational firms. The model is designed to capture the above stylized facts, in particular, 3-5. Specifically, there are two countries and two firms, each of which is originally situated in only one of the two countries. In Stage 1, firms decide whether to build a plant in the foreign country. In Stage 2, they decide whether to relocate R&D activities and, finally, they engage in product-market competition. There are R&D complementarities: If firms carry out R&D in the same location, the resulting cost reduction is greater than if each firm innovates in an isolated location. Further, there are imperfect internal knowledge flows. The results of innovation in one location can be applied elsewhere, but imperfections in communication mean that the resulting cost reduction is smaller.

In our setting, therefore, FDI has a dual role: It allows market access and technology sourcing. However, spillovers are only acquired if firms go beyond the mere imitation of host countries. Firms move to R&D centers where they have to build up absorptive capacity of their own to benefit from spillovers.⁵ The knowledge obtained in these “R&D centers” is transferred to the home countries, where it reduces costs and thus increases profits. For instance, in the financial service industry London has emerged as the dominant research center in Europe. Similarly, in the computer industry, many foreign firms have moved parts of their R&D activities to Silicon Valley, where many of their North-American competitors are also present.

Our model generates the following answers to the four questions posed above: First, FDI liberalization may induce a relocation of R&D activities when intrafirm communication is sufficiently strong, product-market competition is sufficiently weak and external spillovers are sufficiently strong. However, there are potential non-monotone effects of improving intrafirm communication and decreasing relocation costs on the extent of FDI. Sec-

⁵For the notion of absorptive capacity, see Cohen and Levinthal 1990, Leahy and Neary 1997, von Graevenitz 2004.

ond, though there are also conceivable countereffects, large markets are particularly attractive as R&D hosts because the knowledge generated in the subsidiaries can then also be used to improve competitiveness in those markets. Third, compared to a setting without the possibility of R&D relocation, FDI becomes more attractive. Fourth, such a relocation of R&D activities will usually increase domestic welfare since it only occurs if intrafirm communication is well developed and therefore knowledge generated and obtained abroad flows back to the domestic country.

Unlike much of the existing literature on foreign direct investment, we consider only non-tradeable goods. Two reasons justify this. First, our approach generalizes to tradeable goods in a straightforward fashion as long as trade costs are sufficiently high. Second, the service sector and the non-tradeable manufacturing sector comprise about two thirds of the economy in industrialized countries, and both FDI and R&D are becoming increasingly important in these industries, in particular in the service sector (Neven and Siotis 1993, Hackman 1997). For example, for service industries such as banking and finance, general merchandising and telecommunications, to name only a few, FDI is the only feasible form of globalization, so that firms do not face the decision between exporting and becoming multinational that has been highlighted elsewhere. Given the growing importance of R&D in the service sector, our question about the location of R&D in the process of FDI is relevant and complements the work on the decision between exports and FDI.

The strategic analysis of R&D location decisions by multinationals has been examined by other authors. Most closely related is Belderbos et al. (2005) who also provide a theory of R&D locations. Several other studies discuss FDI decisions in their relation to innovation and spillovers, without discussing R&D locations. Examples include Siotis (1999), Petit and Sanna-Randaccio (2000), Bjorvatn and Eckel (2001), Norback (2001), and Sanna-Randaccio and Veugelers (2002). We discuss the relation between these papers and our approach more carefully in an extra section.

We proceed as follows. In section 2, we lay out the structure of the model. In Section 3, we analyze the equilibrium structure of the R&D location game. The central Section 4 shows which subgame perfect equilibria can arise for the FDI game. The focus is on the factors leading to research relocation, and on its welfare effects. Section 5 discusses welfare effects. In Section 6, we discuss related literature. Section 7 concludes.

2 The Model

2.1 Stages of the game

Consider the following three-stage game. There are two firms, $k = 1, 2$ and two countries, $s = 1, 2$. Suppose that initially firm 1 has a plant in country 1, and firm 2 has a plant in country 2. The firms' actions can be summarized as follows.

Stage 1: Firms decide whether to carry out FDI ($l_k = I$) or not ($l_k = N$).

Stage 2: Firms choose R&D locations, r_k ($k = 1, 2$).

Stage 3: Product market competition takes place.

In Stage 1, each firm decides whether to become multinational, that is, whether to build an additional plant in the country where it has no production facilities, at a fixed cost of $F > 0$ which could include the actual costs of building a plant as well as the costs of market access, such as advertising outlays.

In Stage 2, firms decide whether to continue to carry out their R&D activities (or “innovate”) at home ($r_k = H$) or whether to relocate them to the other country ($r_k = A$). We assume, however, that such relocation (or offshoring) is only possible if the firm has carried out FDI.⁶ Relocation involves fixed costs $R > 0$. We assume that the impact of R&D decisions on the marginal production costs in a particular location depends on production and R&D choices in a manner that reflects the extent to which external and

⁶This is consistent with item (ii) in Stylized Fact 5.

internal knowledge flows take place.

If both firms k carry out their R&D in different countries there are no external spillovers by assumption. Each firm achieves a cost reduction of Δ ($\Delta > 0$) for the goods produced in the country s where R&D is carried out, which is to be interpreted as being exclusively the fruit of its own research.

If the firms locate R&D in the same country, there are interfirm (external) spillovers within each country. Some of the knowledge obtained in the process of innovation by one firm will be disseminated to the other firm in the same country. This assumption is plausible if foreign direct investment takes place close to the R&D locations of domestic firms, so that locational knowledge spillovers as discussed by Marshall (1920) are likely. The assumption that external spillovers only arise in locations where both firms have R&D activities is consistent with the notion that firms require absorptive capacity to benefit from spillovers (Cohen and Levinthal 1990, Leahy and Neary 1997, von Graevenitz 2004). To capture the external spillovers, we assume that, in a country where both firms are present and carry out R&D, firms obtain a cost reduction of $(1 + \varepsilon) \Delta$, where $\varepsilon > 0$. The parameter ε can be interpreted as a measure of R&D complementarities.

Next, we capture the idea that intrafirm knowledge transfer plays an important role in multiplant firms because it helps to avoid duplication in research efforts. This has long been recognized as a reason for the emergence of multinational firms (Dunning 1981, Caves 1996).⁷ We assume that a fraction $\gamma \in [0, 1]$ of any cost reduction that a firm achieves at one location, gets carried over to the other plant of the firm. The polar cases $\gamma = 0$ and $\gamma = 1$ correspond to no internal communication and perfect internal communication, respectively. There are many reasons why intrafirm communication might not be perfect, that is, why $\gamma < 1$ is possible.⁸ Obviously, there could be costs of communication between different plants and costs of intrafirm labor mobility. There might also be incentive problems: if managers of dif-

⁷See Baily and Gersbach 1995 for some evidence.

⁸Gersbach and Schmutzler (1999) and Belderbos et al. (2005) also allow for this possibility.

ferent plants are rewarded according to relative performance schemes, they may not be willing to release all relevant information.

In Stage 3, both firms take production decisions. Markets are segregated, that is, we consider only non-tradeable goods or services. Total local demand in country s is a decreasing function $D_s(p_s)$ of the price p_s . Suppose firm k 's marginal costs in country s are constant and given as $c_{ks} = h - \delta_{ks} \cdot \Delta$, where h denotes marginal costs if no cost reduction takes place and δ_{ks} is an indicator function that captures the country s under consideration and the R&D locations of both firms. Specifically, δ_{ks} can take four values:

- $\delta_{ks} = 1$ in countries s where only firm k innovates
- $\delta_{ks} = 1 + \varepsilon$ in countries s where both firms innovate
- $\delta_{ks} = \gamma(1 + \varepsilon)$ in countries s such that both firms innovate in $s' \neq s$
- $\delta_{ks} = \gamma$ in countries s such that only firm k innovates in $s' \neq s$

We assume that $h \geq (1 + \varepsilon) \Delta$ such that marginal costs cannot become negative.

If firm k is the only producer in location s ,⁹ it obtains the monopoly profit corresponding to c_{ks} , or equivalently δ_{ks} , which we write as $\Pi^M(\delta_{ks})$. If two firms are at the same location, they engage in duopolistic competition. We do not yet specify the nature of competition. However, we assume that a unique Nash equilibrium of the game exists for arbitrary marginal costs c_{ks} ($k = 1, 2; s = 1, 2$). We denote the resulting profits of firm k in country s , if firm $j \neq k$ has marginal costs $c_{js} = h - \delta_{js}\Delta$, as $\Pi^D(\delta_{ks}, \delta_{js})$. For convenience, we write $\Pi^D(\delta_{ks}) \equiv \Pi^D(\delta_{ks}, \delta_{js})$ if $\delta_{ks} = \delta_{js}$. Depending on the locations of production and R&D, possible product market profits in one location are therefore

$$\Pi^M(1), \Pi^M(\gamma(1 + \varepsilon)), \Pi^D(1 + \varepsilon), \Pi^D(\gamma(1 + \varepsilon)), \Pi^D(1, \gamma), \Pi^D(\gamma, 1).$$

⁹Note that this case can only occur for $k = s$.

Assuming that the unique equilibrium will be played in the product market stage, the game can be reduced to the first two stages, that is, to the choice of production locations and innovation locations. The following assumption gives very weak conditions on the nature of oligopolistic interaction.

Assumption 1 (a) $\Pi^D(\delta_{ks}, \delta_{js})$ is non-decreasing in δ_{ks} and non-increasing in δ_{js} for $k = 1, 2$ and $j \neq k$.

(b) $\Pi^D(\gamma(1 + \varepsilon)) < \Pi^D(1 + \varepsilon)$.

Part (a) is satisfied in virtually all conceivable oligopoly models; part (b) is clearly satisfied whenever the positive effect of lower own costs on profits dominates over the negative effect of lower competitor costs. This requires very reasonable assumptions on demand elasticities (Shapiro 1989).

3 Analyzing the R&D subgames

3.1 The general model

We can treat the model as a two-stage game with decisions on FDI preceding decisions on R&D locations. There are four second-stage games, (I, I) , (I, N) , (N, I) , (N, N) , the last of which is degenerate as it does not involve any R&D decisions.

The subgames (I, N) and (N, I) : These subgames are analogous; only the firm that has carried out FDI takes an R&D decision. If this firm offshores R&D, it obtains payoffs $\Pi^M(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) - F - R$; if not, its payoffs are $\Pi^M(1) + \Pi^D(\gamma, 1) - F$. The following simple result immediately follows.

Proposition 1 *Suppose $l_k = I$ for only one firm. Then there is an equilibrium where this firm chooses offshoring ($r_k = A$) if and only if*

$$\Pi^M(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) \geq \Pi^M(1) + \Pi^D(\gamma, 1) + R. \quad (1)$$

Clearly, high R&D complementarities (ε) and low relocation costs (R) favor offshoring. Interestingly, however, at this level of generality, the effects

	$r_2 = H$	$r_2 = A$
$r_1 = H$	$\Pi^D(1, \gamma) + \Pi^D(\gamma, 1) - F$	$\Pi^D(1 + \varepsilon) + \Pi^D(\gamma(1 + \varepsilon)) - F - R$
$r_1 = A$	$\Pi^D(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) - F$	$\Pi^D(1, \gamma) + \Pi^D(\gamma, 1) - F - R$

Table 1: Subgame I,I

of improved intrafirm communication on R&D are still somewhat ambiguous, as both sides of (1) are increasing in γ . Intuitively, as communication improves, knowledge generated in the offshore R&D center is more valuable in increasing monopoly profits at home; at the same time, however, knowledge generated at home also is more useful in increasing profits abroad. However, the first effect would appear to dominate; at least the Cournot example in Section 5 confirms that offshoring becomes more likely as communication improves.

The subgame (I, I) : Payoffs are given by Table 1.

Depending on parameters, the subgame equilibria can therefore be characterized as follows.

Proposition 2 (i) *Suppose*

$$\Pi^D(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) \geq \Pi^D(1, \gamma) + \Pi^D(\gamma, 1) + R \quad (2)$$

Then there are two pure-strategy equilibria, (A, H) and (H, A) . Thus, the equilibria involve offshoring.

(ii) *Suppose condition (2) does not hold.*

(a) *Suppose*

$$\Pi^D(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) \leq \Pi^D(\gamma, 1) + \Pi^D(1, \gamma) - R \quad (3)$$

Then, there are two pure-strategy equilibria, (A, A) and (H, H) .

(b) *If condition (3) does not hold, the equilibrium (H, H) is unique.*

First, consider condition (2) which guarantees the existence of offshoring equilibria. This condition clearly requires that R&D complementarities are

sufficiently large relative to relocation costs, so that one firm is willing to bear the cost of offshoring in order to benefit from spillovers. Clearly, there is a “chicken” structure in the relocation game, with each firm preferring the other one to move: While product market profits are the same for both firms, the firm that carries out R&D offshore has to bear the relocation costs.

Second, note that the offshoring equilibrium requires that competition is not too intense; otherwise firms would prefer differentiating each other in terms of R&D locations so as to soften competition.¹⁰ Conversely, if condition (2) does not hold, firms prefer differentiation of R&D locations. Obviously, the most efficient way of achieving this is if neither firm relocates, which happens in the equilibrium (H, H) . However, for low relocation costs, there is another equilibrium (A, A) . Condition (3) makes sure this equilibrium exists, even though it is Pareto dominated. For simplicity, we ignore the implausible equilibrium (A, A) in the following, so that the equilibrium structure in subgame (I, I) is fully determined by whether (2) holds.

Third, the effects of improving communication are again somewhat ambiguous: As γ increases, so does $\Pi^D(\gamma(1+\varepsilon))$. Intuitively, improving communication increases home profits for a firm that offshores. On the other hand, $\Pi^D(\gamma, 1) + \Pi^D(1, \gamma)$, the total duopoly profits of a firm that does not offshore, could increase too. Even though a firm that does not offshore faces tougher competition at home from the competitor that uses knowledge generated abroad ($\Pi^D(1, \gamma)$ decreases as γ increases), it can similarly compete more effectively abroad, using knowledge generated at home ($\Pi^D(\gamma, 1)$ increases). Again, our numerical example will suggest that nevertheless improvements in communication tend to induce offshoring.

We summarize our findings as follows.

Corollary 1 : (i) *In each subgame of the R&D game, offshoring is more likely if R&D complementarities are strong and relocation costs are low.*
(ii) *When both firms have carried out FDI, offshoring is more likely when*

¹⁰As an extreme case, under homogeneous Bertrand competition, the left-hand side of (2) is always zero, so that the condition cannot hold.

competition is weak.

(iii) The effect of improved intrafirm communication on offshoring is ambiguous.

4 Subgame-Perfect Equilibria

We now analyze the subgame-perfect equilibria of the two-stage game. The main goal of this section is to understand under which conditions research relocation takes place along with FDI. The preceding analysis suggests that we should distinguish between different parameter regions, according to the outcome of the R&D game. If (1) and (2) both hold, there will be offshoring no matter whether one or two firms have carried out FDI; we denote this parameter regime as LRC (“low relocation costs”). If (1) and (2) are both violated, there will be no offshoring in either type of subgame; we shall call the regime HRC (“high relocation costs”).

In the numerical example below, it will turn out that (1) typically holds whenever (2) does. We shall thus refer to the case where (1) holds, but (2) does not as MRC (“medium relocation costs”) and ignore the case that (2) holds, but (1) does not. In MRC, offshoring only takes place if one firm has carried out FDI. We thereby ignore the theoretical possibility that R&D offshoring takes place in subgame (I, I) , but not in the subgames (I, N) and (N, I) , as this possibility does not arise for our parametrizations of the Cournot game.

4.1 The LRC-Regime

In regime LRC, characterized by conditions (1) and (2), relocation costs are so low that R&D offshoring takes place in any subgame that involves FDI. This limits the candidates for equilibria as follows:

1. No FDI: (N, N)
2. Asymmetric FDI with R&D offshoring: $((I, A); N)$

3. Symmetric FDI with R&D offshoring: $((I, H); (I; A))$

The following proposition describes the equilibrium structure in regime LRC.

Proposition 3 *In regime LRC:*

(i) *The No-FDI Equilibrium exists if and only if:*

$$\Pi^M(1) \geq \Pi^M(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) - F - R \quad (4)$$

(ii) *The Asymmetric FDI Equilibrium (with offshoring) exists if and only if the following two conditions hold simultaneously:*

$$\Pi^D(\gamma(1 + \varepsilon)) - F - R \leq 0 \quad (5)$$

$$\Pi^M(1) \leq \Pi^M(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) - F - R \quad (6)$$

(iii) *The Symmetric FDI Equilibrium (with offshoring) exists if and only if:*

$$\Pi^D(\gamma(1 + \varepsilon)) - F - R \geq 0. \quad (7)$$

The LRC condition not only guarantees that offshoring must take place along the equilibrium path for any equilibrium with FDI; in addition, it must also occur for each first-period deviation from any equilibrium, with or without FDI. Therefore, condition (4) guarantees that the no-FDI equilibrium profit is higher than the profit in the deviation subgame, which involves offshoring. As to the Asymmetric FDI Equilibrium, by condition (5), the firm which does not carry out FDI does not want to deviate and invest, assuming that it would relocate itself in case it deviated to the game (I,I).¹¹ (6) is the best-response condition for the investor. For the Symmetric FDI Equilibrium, (7) makes sure both firms want to invest, bearing in mind that the competitor would relocate in the equilibrium of the deviation game.¹²

¹¹Clearly, the assumption that the firm would relocate itself in the case of deviation makes deviation less attractive than the alternative assumption that the competitor bears the burden of relocation, in which case condition (5) becomes $\Pi^D(\gamma(1 + \varepsilon)) - F \leq 0$.

¹²This condition guarantees that even the firm that bears the burden of relocation prefers this to deviation.

4.2 The MRC Regime

In the MRC regime with intermediate relocation costs, offshoring takes place in the subgames (I, N) and (N, I) , but not in the subgame (I, I) . This reduces the equilibrium candidates as follows.

1. No FDI: (N, N) ;
2. Asymmetric FDI with R&D offshoring: $((I, A); N)$;
3. Symmetric FDI without R&D offshoring $((I, H); (I, H))$.

The following proposition describes the equilibrium structure in regime MRC.

Proposition 4 *In regime MRC:*

(i) *A No-FDI equilibrium (N, N) exists if and only if*

$$\Pi^M(1) \geq \Pi^M(\gamma(1+\varepsilon)) + \Pi^D(1+\varepsilon) - F - R. \quad (8)$$

(ii) *An Asymmetric FDI Equilibrium $((I, A); N)$ exists if and only if the following conditions hold simultaneously:*

$$\Pi^D(1+\varepsilon) \geq \Pi^D(1, \gamma) + \Pi^D(\gamma, 1) - F \quad (9)$$

$$\Pi^D(1+\varepsilon) + \Pi^M(\gamma(1+\varepsilon)) - F - R \geq \Pi^M(1). \quad (10)$$

(iii) *A Symmetric FDI equilibrium $((I, H); (I, H))$ exists if and only if*

$$\Pi^D(1, \gamma) + \Pi^D(\gamma, 1) - F \geq \Pi^D(1+\varepsilon). \quad (11)$$

Again, the MRC condition not only restricts the behavior along the equilibrium path, but also for every deviation subgame. Intuitively, condition (8) makes sure that the profits in the No-FDI case are higher than under deviation to FDI, bearing in mind that the firm would relocate following such a deviation. Now consider the Asymmetric FDI Equilibrium. Condition (9) makes sure the non-investor does not want to invest in Stage 1; (10) guarantees that the investing firm does not want to deviate by not investing. Condition (11) is the symmetric first-stage no-deviation condition, bearing in mind that, following deviation, the firm that does not deviate would relocate.

4.3 The HRC Regime

In the HRC regime, R&D offshoring does not take place in any subgame. This reduces the equilibrium candidates as follows.

1. No FDI: (N, N) ;
2. Asymmetric FDI without R&D offshoring: $((I, H); N)$;
3. Symmetric FDI without R&D offshoring $((I, H); (I, H))$.

The following proposition describes the equilibrium structure in regime HRC.

Proposition 5 *In regime HRC:*

(i) *A No-FDI equilibrium (N, N) exists if and only if*

$$0 \geq \Pi^D(\gamma, 1) - F. \quad (12)$$

(ii) *An Asymmetric-FDI Equilibrium $(I, H; N)$ exists only if*

$$0 = \Pi^D(\gamma, 1) - F. \quad (13)$$

(iii) *A Symmetric FDI equilibrium $(I, H; I, H)$ exists if and only if*

$$\Pi^D(\gamma, 1) - F \geq 0. \quad (14)$$

Intuitively, as there can be no R&D offshoring on the equilibrium path or in any deviation subgame, firms will earn $\Pi^D(\gamma, 1) - F$ in an FDI location. Thus, carrying out FDI is worthwhile if and only if $\Pi^D(\gamma, 1) > F$.

4.4 Comparative Statics

Propositions 3, 4 and 5 have simple comparative statics implications.

Corollary 2 : *Parameter changes that do not affect the R&D regime have the following effects on FDI.*

(1) *An equilibrium without FDI becomes less likely as fixed costs F or relocation costs R fall, R&D complementarities ε increase or internal communication γ improves.*

(2) *A symmetric FDI equilibrium where both firms carry out FDI becomes more likely if fixed costs F and relocation costs R fall.*

Note that the effects of the remaining parameters on the chances of obtaining a symmetric FDI equilibrium are ambiguous. For instance, in regime LRC such an equilibrium, which would involve offshoring, becomes more likely as R&D complementarities increase. In regime MRC, there would be no offshoring in the proposed symmetric FDI equilibrium, but offshoring would arise in case of a deviation to a situation where only one firm invests. Thus, high R&D complementarities ε make a symmetric FDI less likely in regime MRC.

An important limitation of these comparative-statics results is that they are stated for fixed R&D regimes. As we saw in Section 3, the R&D regime itself depends on parameters, so that Corollary 2 gives an incomplete picture of the effects of parameters on FDI. Clearly, however, by combining Propositions 1 and 2 with Propositions 3, 4 and 5, it is straightforward to describe the full equilibrium structure of the game in terms of fundamentals. Writing up the conditions in the general form is, however, somewhat cumbersome, so that we shall focus on a numerical analysis instead.

5 The Cournot Example

We consider a simple Cournot example, with linear demand function $D(p) = a - p$. Defining $\alpha \equiv a - h$, we can use the standard formulas (for $k \neq j$):

$$\Pi^M(\delta_{ks}) = \frac{(\alpha + \delta_{ks}\Delta)^2}{4}; \quad \Pi^D(\delta_{ks}, \delta_{js}) = \frac{(\alpha + 2\delta_{ks}\Delta - \delta_{js}\Delta)^2}{9}$$

to calculate the various equilibrium profits.

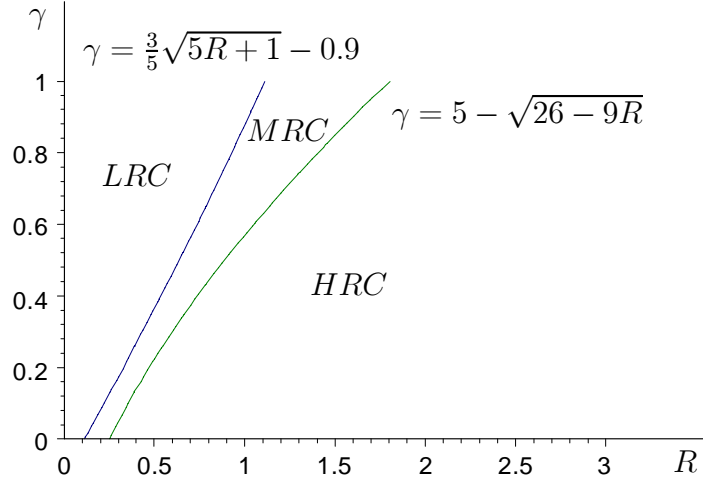


Figure 1: The R&D Game

5.1 The R&D Game

We use a special parametrization, $(\varepsilon = 1, \alpha = 1, \Delta = 1)$ to delineate the parameter regions for the relocation game in $(R; \gamma)$ -space. In Figure 1, the right line corresponds to

$$\Pi^M(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) = \Pi^M(1) + \Pi^D(\gamma, 1) + R \quad (15)$$

for these parameter values, that is, to the boundary of the region given by (1). Similarly, the left line corresponds to

$$\Pi^D(\gamma(1 + \varepsilon)) + \Pi^D(1 + \varepsilon) = \Pi^D(1, \gamma) + \Pi^D(\gamma, 1) + R, \quad (16)$$

that is, to the boundary of the region given by (2).

Thus, to the left of the two lines, regime LRC obtains, that is, for sufficiently low values of R , offshoring takes place in the subgames (I, N) and (N, I) as well as in the subgame (I, I) . For sufficiently high values, to the right of the two lines, there is no offshoring in any of these subgames (regime HRC). In the middle, offshoring only takes place for the subgames (I, N) and (N, I) , but not for (I, I) (regime MRC). In a similar vein, improved communication tends to make relocation more likely.

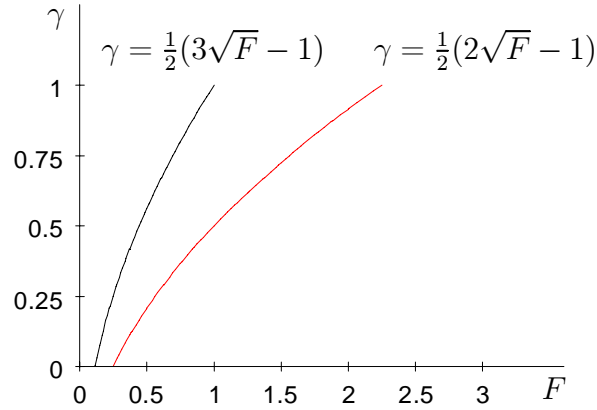


Figure 2: The FDI Game (*LRC*)

5.2 FDI equilibria for fixed R&D-regime

We first apply Propositions 3, 4 and 5 directly to describe the FDI equilibrium structure for each of the regimes LRC, MRC and HRC.

5.2.1 LRC

The simplest way to present the LRC case is to confine attention to the boundary case $R = 0$. Figure 2 describes the equilibrium structure for this case in $(F; \gamma)$ -space, using our standard parametrization $\alpha = 1, \varepsilon = 1, \Delta = 1$. Clearly, we are in regime LRC, no matter which value γ takes. Therefore, we can apply Proposition 3. To the left of the left line, the only equilibrium has both firms investing, and one country emerging as the research center. As fixed costs increase (or the communication parameter γ falls), only one firm carries out FDI and relocates its R&D activities. For still higher fixed costs (and lower γ), the only equilibrium has no FDI.

5.2.2 MRC

To analyze FDI in regime MRC, we first choose a value of R for which all three R&D regimes obtain for suitable levels of γ . Specifically, we choose

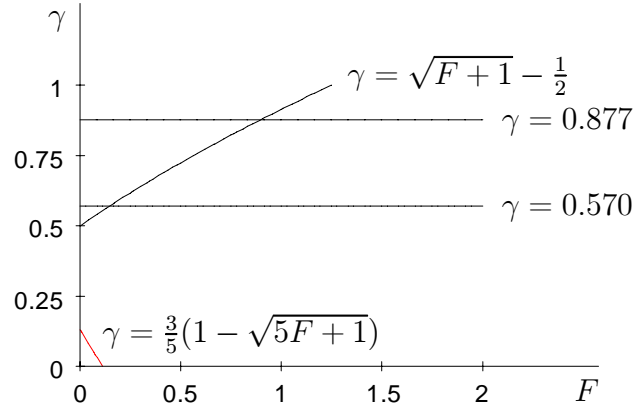


Figure 3: The FDI Game (*MRC*)

$R = 1$. Then *MRC* obtains for $\gamma \in [0.570, 0.877]$. Thus, we can restrict attention to the area between the parallel lines in Figure 3.

In this area, there is no FDI in the region to the right of the upward-sloping line. To the left of the line, the Asymmetric FDI Equilibrium arises. The Symmetric FDI Equilibrium does not occur for these parameters lines. Intuitively, the high value of the R&D-complementarity parameter ($\varepsilon = 1$) makes an equilibrium with FDI but without relocation unlikely.

5.2.3 HRC

For sufficiently high values of relocation costs, relocation *HRC* will obtain. Then, given the remaining parameters of the Cournot example, we are in regime *HRC* for arbitrary values of γ (See Figure 1). Figure 4 shows that for well-developed intrafirm communication and low fixed cost FDI takes place.

5.3 FDI equilibria for variable R&D-regime

We now combine the analysis of the last two subsections, describing how the FDI-equilibrium depends on parameters when we take into account that the R&D regime is potentially affected by parameter changes.

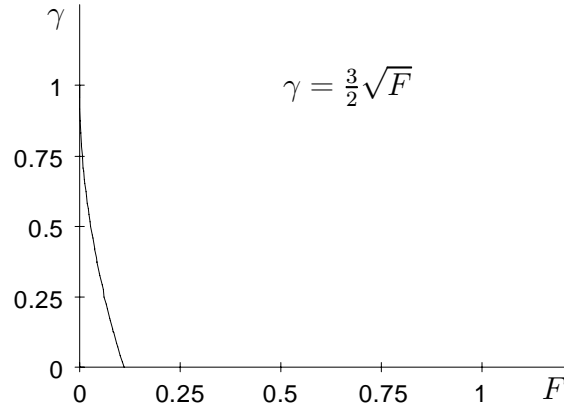
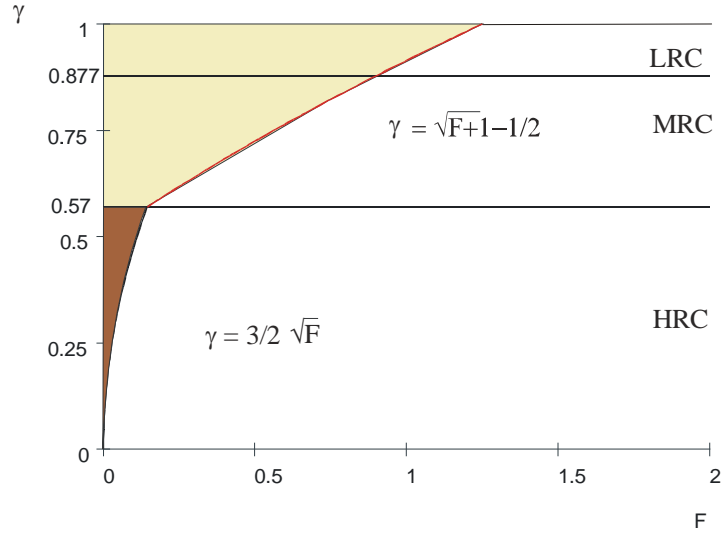


Figure 4: The FDI Game (*HRC*)

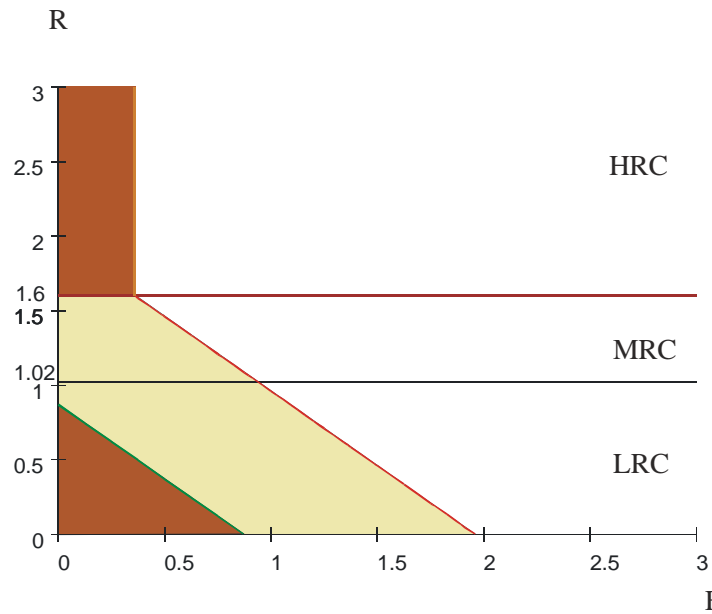
Figure 5 describes the structure of FDI equilibria, depending on fixed costs F and the internal spillover parameter γ . As above, we set parameters $\varepsilon = 1$, $\alpha = 1$, $\Delta = 1$. Relocation costs are set to $R = 1$, so that all three R&D regimes arise for the given values of the other parameters. Recall that the boundary between LRC and MRC is given by $\gamma = 0.57$ and the boundary between MRC and HRC is given by $\gamma = 0.877$. To the right of the upward sloping line, there is no FDI. The equilibrium structure to the left of the line depends on the regime, however. For instance, fix $F = 0.1$. For low values of γ , regime HRC obtains and there is no FDI (dark area). As γ increases, the equilibrium switches to symmetric FDI. For still higher values, the regime MRC is reached. From there on, the equilibrium involves asymmetric FDI with offshoring (lightly shaded area). Interestingly, therefore, improvements of internal communication have ambiguous effects on FDI once the endogeneity of R&D location is taken into account. For high levels of fixed costs, an increase in γ can only lead from "No FDI" to an equilibrium with asymmetric FDI. For low levels of fixed costs, however, the FDI behavior can depend on γ in a non-monotone fashion: For very bad internal communication, the equilibrium is "No FDI". As communication improves, there is a symmetric FDI equilibrium. As communication improves

even more and the R&D-regime shifts to MRC, the equilibrium shifts to asymmetric FDI.



The Effects of Intrafirm Communication on FDI

An alternative approach to understanding the comparative statics of FDI can be obtained from Figure 5. This shows how the equilibrium structure depends on fixed costs and R&D relocation costs. This figure is drawn for the same parameter values as Figure 5, except that we fixed $\gamma = 0.9$, while keeping R variable. Again, the two horizontal lines describe boundaries between R&D regimes. Note, however that the lower line ($R = 1.02$) now corresponds to the boundary between LRC and MRC, whereas the upper line ($R = 1.6$) is the boundary between MRC and HRC. The effects of increasing relocation costs are non-monotone when fixed costs are low. For small relocation costs, there is an equilibrium with symmetric FDI. As relocation costs increase, the equilibrium changes to "Asymmetric FDI with offshoring". As R increases further, regime MRC is reached, but the equilibrium remains the same. For sufficiently high relocation costs, however, HRC is reached, and the equilibrium shifts to symmetric FDI without offshoring again.



The Effects of Relocataion Costs on FDI (All Regimes)

5.4 Summary

The Cournot example reveals several interesting insights. First, for given R&D regime, improved communication unambiguously makes more FDI more likely. Second, when the endogeneity of FDI is taken into account, improved communication can have non-monotone effects on FDI, with the equilibrium from “No FDI” to “Symmetric FDI” and finally to a symmetric FDI. Third, however, improved communication always makes “No FDI” less likely. Fourth, taking offshoring into account always makes “No FDI” less likely. Fifth, however, changes in relocation costs can have non-monotone effects on the FDI equilibrium.

6 The Welfare Effects of Foreign Direct Investment

The welfare effects of FDI on source countries and recipients have been the subject of considerable debate, and they are often regarded as ambiguous when both countries are taken into account.¹³ Based on our analysis, we can obviously not give a complete discussion of this point, as we are only dealing with FDI in non-tradeables.

First, welfare discussions of offshoring typically put particular emphasis on employment effects that we do not address. Second, we only treat non-tradeables. Therefore, the important issue that foreign direct investment may substitute for exports does not arise. However, this allows us to fully concentrate on the welfare effects associated with knowledge transfers: we add a subtle aspect to the discussion of the welfare effects of R&D by analyzing whether R&D relocation would lead to welfare gains.

Proposition 6 *Suppose $\gamma(1 + \varepsilon) > 1$. Further, suppose the equilibrium is $(N; (I, A))$, thus involving FDI and relocation by firm 2. Then, welfare in country 2, defined as the sum of consumer surplus and producer surplus, net of fixed costs and relocation costs, is higher than it would be if no firm invested in FDI. In country 1 the consumer surplus increases, whereas the effect on producer surplus is ambiguous.*

Proof. For research relocation to be an equilibrium, profits for firm 2 must be higher than in the reference case that no firm invests. Thus, a sufficient condition for welfare to increase is that consumer surplus does. As country 2 is served by a monopoly no matter whether relocation takes place or not, the consumer surplus will increase if and only if the costs are lower with relocation than without. This will be true whenever the cost reduction

¹³See Grossman and Helpman 1991, Neven and Siotis 1993, Caves 1996, Sanna-Randaccio 1996, Markusen and Venables 1997 and Graham and Krugman 1989 for an assessment of the arguments.

from external spillovers dominates over the cost increase from having to rely on internal communication, that is, whenever $\gamma(1 + \varepsilon) > 1$. ■

The role of the assumption that $\gamma(1 + \varepsilon) > 1$ here is to make sure that market access in country 1 in itself does not suffice to induce firm 2 to move to country 1. Without this assumption, home-country consumer surplus might decline as a result of research relocation.

7 The Impact of Market Size

The empirical literature suggests that offshoring locations are more likely to emerge in larger markets. In the following, we give theoretical support for this statement, albeit with a qualification. We show that, under certain reasonable parameter constellations, the larger country is more likely to emerge as the offshoring location, but there are also conceivable situations where the smaller market is the offshoring host.

To understand this, we first refine our notation, and denote the monopoly profit of firm k in country s as $\Pi_{ks}^M(\delta_{ks})$ and the duopoly profit if the firm faces firm $j \neq k$ as $\Pi_{ks}^D(\delta_{ks}, \delta_{js})$. Note again that in the monopoly case $k = s$. We assume that country $s = 1$ is the larger market, which is captured as follows.

Assumption 2 (i) $\Pi_{11}^M(\delta_{11}) > \Pi_{22}^M(\delta_{22})$ if $\delta_{11} = \delta_{12} \geq 0$.
(ii) $\Pi_{k1}^D(\delta_{k1}, \delta_{j1}) > \Pi_{k2}^D(\delta_{k2}, \delta_{j2})$ for all $k \in \{1, 2\}$, $j \neq k$ if $(\delta_{k1}, \delta_{j1}) = (\delta_{k2}, \delta_{j2})$.
(iii) $\frac{\partial \Pi_{11}^M}{\partial \delta_{11}}(\delta_{11}) > \frac{\partial \Pi_{22}^M}{\partial \delta_{22}}(\delta_{22})$ if $\delta_{11} = \delta_{22} \geq 0$.

The role of parts (i) and (ii) is obvious: For arbitrary cost constellations, both monopoly and duopoly profits are higher in country 1 than in country 2. Part (iii) is a similar assumption on the marginal effects of cost reductions, saying that the value of a cost reduction is greater in the larger country.

We now ask whether Assumption 2 is sufficient to guarantee that an asymmetric FDI Equilibrium is more likely to occur in Country 1 than in

Country 2. We confine ourselves to the simple case of the LRC-regime; with $R = 0$. Denote the initial location of firm k (j) as s (s'). Applying the arguments of Proposition 3, the conditions for an Asymmetric FDI Equilibrium in Country s' are

$$\Pi_{js}^D(\gamma(1+\varepsilon)) \leq F \quad (17)$$

$$F \leq \Pi_{ks'}^D(1+\varepsilon) + \Pi_{ks}^M(\gamma(1+\varepsilon)) - \Pi_{ks}^M(1) \quad (18)$$

Condition (17) is the no-deviation condition for the non-investor that is based in country s' ; inequality (18) is the corresponding condition for the investor that is based in country s .

Clearly, (17) is easier to satisfy if the large country 1 is the offshoring host s' : For the non-investor, deviating from an asymmetric FDI equilibrium in a large country by investing in the small country is less attractive than deviating from an asymmetric FDI equilibrium in a small country by investing in the large country. A similar effect is present in (18), the no-deviation constraint for the investor. $\Pi_{ks'}^D(1+\varepsilon)$ is greater in the large country $s' = 1$ which, other things being equal, makes FDI in the large country more attractive. However, assuming that internal and external spillovers are sufficiently large that $\gamma(1+\varepsilon) > 1$, a counter-effect emerges. $\Pi_{ks}^M(\gamma(1+\varepsilon)) - \Pi_{ks}^M(1)$ is higher if s is the large country. Thus, there is a reason why, in principle, an asymmetric equilibrium with research relocation might emerge in the small country, but not in the large country: The spillover benefits to the monopoly location are greater when this monopoly location is larger.

In spite of this possibility, for the Cournot example, the research center is indeed likely to emerge in the large country. To see this, suppose that the size of a market is given by the value of the parameter α_l ; then the following proposition shows.

Proposition 7 *In the Cournot example, suppose that $\gamma(1+\varepsilon) > 1$. Then, if the parameters are such that a research center in the small country 2 emerges, there must also be an equilibrium with a research center in the large country 1.*

The proof is straightforward. By the above arguments, the statement is true if

$$\Pi_{21}^D(1 + \varepsilon) + \Pi_{22}^M(\gamma(1 + \varepsilon)) - \Pi_{22}^M(1) \geq \Pi_{12}^D(1 + \varepsilon) + \Pi_{11}^M(\gamma(1 + \varepsilon)) - \Pi_{11}^M(1),$$

which, using $\gamma(1 + \varepsilon) > 1$, holds if

$$\Pi_{21}^D(1 + \varepsilon) + \Pi_{11}^M(1) - \Pi_{11}^M(\gamma(1 + \varepsilon)) \geq 0.$$

In the Cournot case, this is equivalent to

$$\frac{2}{9}\alpha_2 + \Delta \left(\frac{1}{2}\gamma + \frac{2}{9}\varepsilon + \frac{1}{2}\gamma\varepsilon - \frac{5}{18} \right) \geq 0. \quad (19)$$

This condition clearly is implied by $\gamma(1 + \varepsilon) > 1$.

8 Related Literature

In this section, we discuss the relation between our paper and existing literature. To repeat, the key features of our analysis are as follows.

1. Both the location of production and the location of R&D are endogenous.
2. There are two segregated countries.
3. There are external locational spillovers and internal spillovers.
4. R&D levels are exogenous.
5. Local product-market competition is treated in reduced form, with the Cournot case used for purposes of illustration.

Our own paper (Gersbach and Schmutzler 1999) also treats production and R&D locations as jointly endogenous. Also, the spillover technology we use in the present paper, with both intrafirm and interfirm spillovers goes

back to this earlier contribution. However, the original paper addresses very different questions. In a setting where local competition is of an intense type (à la Bertrand), we ask under which circumstances multi-plant firms are nevertheless prepared to produce in some joint location so as to benefit from technology sourcing to increase profits in other locations. By the very nature of this exercise, the paper requires at least three locations, which makes it much more complex than the present paper.

By far the most closely related contribution is Belderbos, Lykogianni and Veugelers (2005), henceforth BLV.¹⁴ These authors also investigate the determinants of R&D locations of multinational firms, asking how these choices depend on various parameters, including the spillover parameters we consider. There are several similarities to our paper. BLV also consider duopolists operating in segmented markets. Both external and internal spillovers are allowed; like in our present paper, the spillover technology builds from Gersbach and Schmutzler (1999). Also, the total R&D level is fixed, the only issue being R&D location.

There are several differences, however. Most importantly, BLV concentrate exclusively on choices of R&D locations, assuming that both firms operate in both markets. Also, the role of the relative product market size in the two countries for these locational decisions is not analyzed. Finally, BLV do not treat welfare issues. However, BLV are more general in other dimensions. For instance, firms are not restricted to a single R&D location. Rather, they can spread their budget arbitrarily over the two locations. Moreover, BLV allow for asymmetries between firms, so that different effects of parameter changes on the locational choices of technology leaders and laggards, respectively, can be considered. In fact, most of their results concern these differential effects, which makes the comparison between the two papers difficult. Most closely related to our analysis, higher external and internal spillovers induce laggards to move more R&D abroad and firms with

¹⁴Lykogianni (2006) contains related material. In addition, the author addresses further issues such as differences in decisions concerning applied and basic research.

a strong lead to invest less R&D abroad.

Petit and Sanna-Randaccio (2000) and Norbäck (2001) also analyze the relation between FDI and R&D decisions. However, both papers consider the extent of R&D rather than the location as an endogenous variable. Like our paper, Petit and Sanna-Randaccio (2000) use a two-country two-firm set-up, with each firm initially located in one country. Products are tradeable, so that, in a first stage of the game, firms can decide whether they want to export or engage in FDI. In addition, they can refrain from serving the foreign market altogether. Before product market competition takes place, firms decide on the level of cost-reducing R&D. R&D locations are not discussed. Whatever the level of cost reduction from R&D or external spillovers, it has the same effects on both locations. The authors first analyze how locational decisions affect investments, then they consider how location choices depend on parameters such as plant fixed costs, R&D productivity and spillovers. Most closely related to our analysis is the result that higher spillovers tend to induce a move from FDI to exports.¹⁵ Norbäck (2001) only considers one firm, asking whether this firm wants to serve the world market by exporting or by FDI. The firm also chooses its R&D level. External spillovers obviously play no role in the analysis, but the author does consider the effects of higher technology transfer costs, corresponding roughly to worse internal spillovers on the choice between FDI and exporting.

9 Conclusions

In this paper, we presented a model of multinational activity that differs from existing work in several respects. Most importantly, we provide the only contribution where FDI and R&D offshoring are both endogenous decisions. We emphasized the role of informational exchange between and within multinationals. Enlargement of markets tends to induce research relocation. More

¹⁵To repeat, however, the external spillover parameter used by Petit and Sanna-Randaccio (2000) differs from ours in that spillovers in their analysis are non-localized.

importantly, in the setting of the model, if equilibrium behavior gives rise to R&D relocation, it results in higher domestic welfare under fairly general conditions.

Our paper sheds light on the popular argument that FDI could lead to a relocation of R&D activities away from the home countries of the investing firms and that this hurts domestic welfare.¹⁶ Our analysis suggests that, in many circumstances, this will only happen if the reverse knowledge flows are sufficiently strong to increase welfare in both countries.

A fruitful extension of our approach would be to merge our analysis with the one of BLV, allowing, like the present paper, for endogenous choices of production locations, but adding the interesting features of BLV that include more general choices of R&D locations as well as a leader-laggard structure.

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¹⁶See Graham and Krugman (1989), Neven and Siotis (1993) for a discussion.

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