Foreign Direct Investment and R&D-Offshoring

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This Version: October 3, 2008

ABSTRACT: We analyze a two-country model of Foreign Direct Investment (FDI) and R&D-offshoring. Two firms, each of which is originally situated in only one of the two countries, first decide whether to build a plant abroad. Then, they decide whether to relocate R&D activities offshore. 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 usually nevertheless increases domestic welfare. Third, the potential of R&D offshoring makes FDI itself more likely.

Keywords: Foreign Direct Investment, R&D, Spillovers, Research Relocation

JEL: F23, O30

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We are grateful to René Belderbos, Thomas Borek, Volker Hahn, Bernhard Pachl, Andreas Polk, Reinhilde Veugelers and seminar participants at K.U. Leuven for helpful comments on an earlier, substantially different, version.

1 Introduction

This paper analyzes the determinants of multinational firms' choices of locations for production and R&D. We start from a set of stylized facts:

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

Global business R&D expenditure in 2002 amounts to $450 billion, of which at least two thirds are carried out by multinationals (UNCTAD 2005). Importantly, R&D offshoring is gaining pace:

Stylized Fact 2 *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). 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).

A large empirical literature investigates what kind of locations are likely to be hosts of R&D offshoring. The findings are summarized as follows.[2]

Stylized Fact 3 *R&D by foreign affiliates is attracted particularly to*
(i) large markets and markets with high per capita income;
(ii) locations where the firms have manufacturing and sales activities;
(iii) countries with large technological know-how (technology sourcing).

Part (iii) 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. For instance, this influenced the location decisions of Japanese firms in the

[1] For similar statements, see Caves (1996, ch. 7), Florida (1997), Belderbos (2001, 2003), Kuemmerle (1999), von Zedtwidtz and Gassmann (2002).

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

U.S. (Kogut and Chang 1991). More generally, the importance of technology sourcing has been documented in many empirical papers.[3]

In spite of their growing importance, R&D offshoring and technology sourcing have hardly been analyzed theoretically. Important questions are:

1. What circumstances favor offshoring and technology sourcing?
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?

We analyze these issues in a simple model that emphasizes internal and external knowledge flows in multinational firms. The model is designed to capture the above stylized facts, in particular, 2 and 3. 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 offshore and, in stage 3, they engage in product-market competition. There are external locational spillovers: 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.

Therefore, FDI has a dual role: Apart from market access, it allows for technology sourcing which requires that firms move to *R&D centers* where they have to build up absorptive capacity of their own to benefit from spillovers. 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

[3]Relevant studies include: Cantwell and Hodson (1991), Håkanson and Nobel (1993), Neven and Siotis (1993), OECD (1994), Baily and Gersbach (1995), Almeida (1996), Florida (1997), Kuemmerle (1997), Branstetter (2000) and Frost (2001), Griffith et al. (2004).

foreign firms moved parts of their R&D activities to Silicon Valley to benefit from the presence of their North-American competitors.

We obtain the following answers to the four questions posed above: First, FDI liberalization may induce R&D offshoring when intrafirm communication is sufficiently strong, product-market competition is sufficiently weak and external spillovers are sufficiently strong. Surprisingly, however, there are potential non-monotone effects of improving intrafirm communication and higher external spillovers on the extent of FDI. Second, compared to a setting without the possibility of R&D relocation, FDI becomes more attractive. Third, offshoring usually increases 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. Fourth, 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.

The R&D decisions of multinationals has been examined by other authors; to our knowledge, however, none of them treats FDI and R&D locations as jointly endogenous. 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 considering offshoring.[4] We discuss the relation between these papers and our approach more carefully in an extra section.

Section 2 introduces the model. In Section 3, we analyze the equilibria of the R&D location game. Section 4 calculates the subgame perfect (FDI) equilibria. Section 5 provides more specific results for a Cournot example. Section 6 discusses welfare effects. Section 7 extends the game to asymmetric countries. Section 8 embeds the analysis into the literature. Section 9 concludes and sketches some generalizations of the model.

[4]Examples include Lin and Saggi (1998), Siotis (1999), Petit and Sanna-Randaccio (2000), Bjorvatn and Eckel (2001), Norbäck (2001), Glass and Saggi (2002), Sanna-Randaccio and Veugelers (2007), Dawid et al. (2008).

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, $s = 1, 2$. 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 or not (*FDI stage*).

Stage 2: Firms choose R&D locations (*offshoring stage*).

Stage 3: Product market competition takes place.[5]

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 $F > 0$. In Stage 2, firms decide whether to continue to carry out their R&D activities (or "innovate") at home (H) or whether to relocate them abroad (A). Each firm therefore has exactly one location where it performs R&D, and relocation is treated as a zero-one decision.[6] We assume that relocation (or "offshoring") is only possible if the firm has carried out FDI.[7] Relocation involves fixed costs $R > 0$.

The impact of R&D decisions on the marginal production costs in a particular location depends on production and R&D choices and the associated external and internal knowledge flows. Specifically, two important considerations are assumed to influence the cost structure:

1. *External spillovers:* When both firms carry out R&D in the same country, they benefit from external knowledge spillovers which allow them to produce at lower marginal costs than if they carry out R&D alone.

This assumption is plausible if FDI takes place close to the R&D locations of domestic firms, so that locational knowledge spillovers 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

[5] In Section 9, we extend our analysis to simultaneous FDI and R&D decisions.

[6] In Section 9, we address the other polar case of continuous R&D decisions.

[7] This is consistent with item (ii) in Stylized Fact 3 that firms tend to locate R&D near production.

and Neary 1997). We refer to a location where both firms perform R&D as *R&D center.*

2. *Intrafirm spillovers*: Knowledge generated in one location is useful in other locations for the same firm, but the resulting cost reduction from R&D is not as large as in the location where the knowledge is generated.

As intrafirm knowledge transfer helps to avoid duplication in research efforts, it has long been recognized as a reason for the emergence of multinational firms (Dunning 1981, Caves 1996).[8] There are many reasons why intrafirm communication might not be perfect, however.[9] 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 different plants are rewarded according to relative performance schemes, they may not be willing to release all relevant information.

The existence of external spillovers and (imperfect) intrafirm knowledge transfer translates naturally into the following assumptions about costs.

1. Marginal costs are lowest, given as $h - \Delta$, in an R&D center, because the firms both benefit from knowledge spillovers and there are no losses from internal transfer of knowledge.

2. Marginal costs are given as $h - \gamma\Delta$ for some $\gamma \in (0, 1)$ in a country when the other country is an R&D center: The firm benefits from external spillovers, but there are losses due to internal knowledge transfer.

3. Marginal costs are given as $h - \beta\Delta$ for some $\beta \in (0, 1)$ in a firm's R&D location if this is not an R&D center. The firm does not benefit from external spillovers, but can use knowledge it has generated locally.

4. In a location where the firm does not have its own R&D location and when there is no R&D center elsewhere, marginal costs are highest, given as $h - \beta\gamma\Delta > 0$: The firm neither benefits from external knowledge spillovers nor can it use knowledge it has generated locally itself.

[8] See Baily and Gersbach (1995) for some evidence.

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

The ranking between the costs in the second and third case (that is, the relative size of β and γ) depends on whether internal spillovers are more effective than external spillovers. For low values of β, external spillovers are essential for cost reduction, because the difference between costs without and with spillovers is $h - \beta\Delta - (h - \Delta) = (1 - \beta)\,\Delta$.

In Stage 3, both firms take production decisions, with marginal costs determined as above. Markets are segregated, that is, we consider only non-tradeable goods or services.[10] Depending on the locations of production and R&D, possible product market profits in one location are denoted by

$$\Pi^M(\beta), \Pi^M(\gamma), \Pi^D(1,1), \Pi^D(\gamma,\gamma), \Pi^D(\beta,\beta\gamma), \Pi^D(\beta\gamma,\beta),$$

using the following conventions: Π^M stands for a monopoly profit; Π^D for a duopoly profit. The entries in brackets stand for cost reductions relative to h: β corresponds to $h - \beta\Delta$, γ corresponds to $h - \gamma\Delta$, etc. When there are two entries, the first one corresponds to the firm whose profits we are considering, the second one to the competitor.[11] Finally, we simplify $\Pi^D(1,1) \equiv \Pi^D(1)$, $\Pi^D(\gamma,\gamma) \equiv \Pi^D(\gamma)$.

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

Assumption 1 *(a) Duopoly profits are decreasing in own costs and increasing in competitor costs.*
(b) $\Pi^D(\gamma)$ *is increasing in* γ*, and* $\Pi^D(\gamma) < \Pi^D(1)$.

Part (a) is satisfied in standard oligopoly models; part (b) is satisfied whenever the positive effect of lower own costs on profits dominates over

[10] 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 (Neven and Siotis 1993, Hackman 1997). For example, for banking and finance, business consulting, general merchandising and telecommunications, FDI is the main form of globalization.

[11] For example, $\Pi^D(1,1)$ thus corresponds to the profits of firms in a research center, $\Pi^D(\beta,\beta\gamma)$ to the duopoly profit of a firm in its home country when there is no offshoring.

the negative effect of lower competitor costs. This requires very reasonable assumptions on demand elasticities (Shapiro 1989).

3 The Offshoring Subgames

We distinguish between offshoring subgames with one and two direct investors.

Subgames with one investor (*Asymmetric FDI*): Only the direct investor takes an offshoring decision. With offshoring, this firm obtains payoffs $\Pi^M(\gamma)+\Pi^D(1)-F-R$; without, its payoffs are $\Pi^M(\beta)+\Pi^D(\beta\gamma,\beta)-F$. Therefore, we obtain:

Remark 1: *Suppose there is only one direct investor. Then there is an equilibrium where this firm chooses offshoring if and only if*

$$\Pi^M(\gamma)+\Pi^D(1)\geq\Pi^M(\beta)+\Pi^D(\beta\gamma,\beta)+R. \qquad (1)$$

Clearly, low relocation costs (R) favor offshoring. Surprisingly, however, at this level of generality, the effects of the remaining parameters are still ambiguous. For instance, both sides of (1) are increasing in γ, so that it is not obvious whether improved communication leads to more offshoring. Intuitively, as communication improves, knowledge generated offshore leads to high monopoly profits at home, but also to high duopoly 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. Similarly, with better external spillovers (lower β), not engaging in offshoring means foregoing greater cost reductions, as $\Pi^M(\beta)$ is increasing in β and $\Pi^D(\beta\gamma,\beta)$ in the first argument. However, lower β also means that the competitor's costs without offshoring are higher; so that $\Pi^D(\beta\gamma,\beta)$ is not necessary increasing in β. Again, in our Cournot example, the offshoring equilibrium is more likely for lower β.

Subgames with two investors (*Symmetric FDI*): The payoffs are given in Table 1.

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

	H	A
H	$\Pi^D(\beta,\beta\gamma) + \Pi^D(\beta\gamma,\beta) - F$ $\Pi^D(\beta,\beta\gamma) + \Pi^D(\beta\gamma,\beta) - F$	$\Pi^D(1) + \Pi^D(\gamma) - F$ $\Pi^D(1) + \Pi^D(\gamma) - F - R$
A	$\Pi^D(\gamma) + \Pi^D(1) - F - R$ $\Pi^D(\gamma) + \Pi^D(1) - F$	$\Pi^D(\beta,\beta\gamma) + \Pi^D(\beta\gamma,\beta) - F - R$ $\Pi^D(\beta,\beta\gamma) + \Pi^D(\beta\gamma,\beta) - F - R$

Table 1: Subgame with symmetric FDI

same for both firms, the firm that carries out R&D offshore has to bear the relocation costs (see Table 1). The subgame equilibria can therefore be characterized as follows.

Remark 2: *Suppose both firms have carried out FDI. If*

$$\Pi^D(\gamma) + \Pi^D(1) \geq \Pi^D(\beta,\beta\gamma) + \Pi^D(\beta\gamma,\beta) + R, \tag{2}$$

there are two pure-strategy equilibria, (A,H) *and* (H,A)*. Thus, the equilibria involve offshoring. If the sign in (2) is reversed, then there is an equilibrium* (H,H)*, that is, without offshoring.*

Several remarks are in order. First, for low relocation costs, the equilibrium (H,H) coexists with another, rather implausible, equilibrium where both firms relocate abroad (A,A). Second, with symmetric FDI, offshoring equilibria require that competition is not too intense; otherwise firms differentiate each other in terms of R&D locations to soften competition.[12] Third, by (2), offshoring requires external spillovers to be large relative to relocation costs, so that one firm is willing to bear the cost of offshoring to benefit from spillovers.[13] Fourth, the effects of improving communication are again ambiguous: By Assumption 1, as γ increases, so does $\Pi^D(\gamma)$. Intuitively, improving communication increases home profits for a firm that offshores. However, $\Pi^D(\beta\gamma,\beta) + \Pi^D(\beta,\beta\gamma)$, the total 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 ($\Pi^D(\beta,\beta\gamma)$ decreases as γ increases), it can also compete more effectively abroad, using knowledge generated at home ($\Pi^D(\beta\gamma,\beta)$ increases). Again, our numerical example will suggest that nevertheless improvements

[12] As competition becomes very intense, the left-hand side of (2) approaches zero, so that the condition cannot hold.

[13] Clearly, if $\beta = 0$, that is R&D complementarities are essential for cost reduction, (2) will always hold for $R = 0$; for $\beta \neq 0$, this is not true in general.

in communication tend to induce offshoring.

4 Subgame-perfect equilibria

To understand under which conditions offshoring takes place along with FDI, we now analyze the subgame-perfect equilibria. The preceding analysis suggests that we should distinguish between different parameter regions, according to the outcome of the R&D game.

1. LRC ("low relocation costs"): If (1) and (2) both hold, offshoring obtains no matter whether one or two firms have carried out FDI.
2. HRC ("high relocation costs"): If (1) and (2) are both violated, there is no offshoring in either type of subgame.
3. MRC ("medium relocation costs"): If (1) holds, but (2) does not, offshoring only takes place if one firm has carried out FDI.[14]

In regime LRC, relocation costs are so low that there is offshoring in any subgame with FDI. This immediately rules out all equilibria except for the following three.

Proposition 1 *In regime LRC:*
(i) The No-FDI Equilibrium exists if and only if:

$$\Pi^M(\beta) \geq \Pi^M(\gamma) + \Pi^D(1) - F - R \tag{3}$$

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

$$\Pi^D(\gamma) - F - R \geq 0. \tag{4}$$

(iii) The Asymmetric FDI Equilibrium (with offshoring) exists if and only if conditions (3) and (4) hold with signs reversed.

[14] In the numerical example below, it will turn out that (1) typically holds whenever (2) does. We shall thus refer to the case as MRC ("medium relocation costs") and ignore the case that (2) holds, but (1) does not. This case is similar to analyze as the MRC case.

Condition (3) guarantees that the no-FDI equilibrium profit is higher than the profit in the deviation subgame, which involves offshoring in LRC. For the Symmetric FDI Equilibrium, (4) makes sure both firms want to invest, bearing in mind that, in LRC, the competitor would relocate in the equilibrium of the deviation game.[15]

In the MRC regime with intermediate relocation costs, the equilibria are different, as a symmetric equilibrium with both firms investing cannot involve offshoring. As in LRC, however, equilibria with symmetric FDI, with asymmetric FDI and without FDI all arise. The Appendix gives the conditions under which each equilibrium arises.

In the HRC regime, R&D offshoring does not take place in any subgame. Thus, the only issue for firms is whether FDI is worthwhile, that is, whether $\Pi^D(\beta\gamma, \beta) \geq F$. If so, the equilibrium involves symmetric FDI; if not, there is no FDI.[16] In the Appendix, the result is stated more carefully.

5 The Cournot example

We consider a Cournot example, with linear demand function $D(p) = a - p$. We can use standard formulas to calculate equilibrium profits. Throughout this section, we choose $\alpha \equiv a - h = 1$, $\Delta = 1$.

5.1 The offshoring game

For these choices of α and Δ, the regime in the offshoring game depends on parameters α, β and R. For sufficiently high relocation costs, there is no offshoring in equilibrium for arbitrary choices of β and γ, so that regime HRC arises.[17] This can be regarded as the benchmark case of a standard FDI model without the possibility of R&D relocation. To allow for the possibility of R&D relocation, we consider $R = 0.5$. Figure 1 gives the values of β and

[15] Equilibrium profits of the offshoring profits are $\Pi^D(1) + \Pi^D(\gamma) - F - R$; deviation profits would be $\Pi^D(1)$.

[16] In the degenerate case that $\Pi^D(\beta\gamma, \beta) = F$ there is also an asymmetric equilibrium where only one firm carries out FDI.

[17] For our parameterization, $R = 2$ is sufficiently high for this to happen.

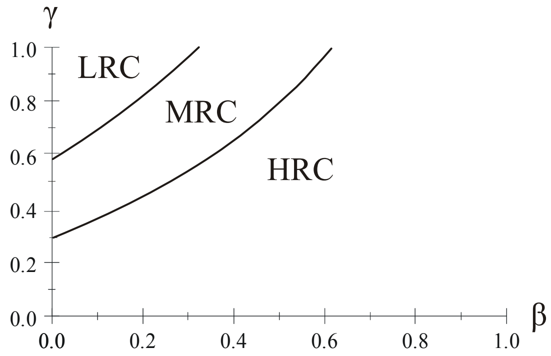

Figure 1: The offshoring game

γ for which each regime arises.[18]

5.2 FDI equilibria

We now describe the subgame-perfect equilibria. We shall compare the benchmark case without relocation (R very large) with the case that $R = 0.5$. In both cases, we shall consider $F = 1$, $F = 0.5$, $F = 0.2$, and $F = 0.1$.

5.2.1 No offshoring

Suppose relocation is too costly for arbitrary values of β and γ. For $F = 1$ and $F = 0.5$, No FDI is the only equilibrium, independent of β and γ. For $F = 0.1$, Symmetric FDI is the only equilibrium. In the intermediate case $F = 0.2$, the equilibrium depends on parameters (see Figure 2), with (symmetric) FDI arising only for good intrafirm communication (γ high) and low external spillovers (β high). Intuitively, when there is offshoring, a firm carries out FDI only to gain market access, resulting in profits $\Pi^D(\beta\gamma, \beta)$. It relies exclusively on its own R&D, and it must transfer its knowledge abroad to benefit from FDI. When external spillovers are essential and/or intrafirm communication is bad, FDI is not worthwhile.

[18] For lower relocation costs, both regime boundaries would shift further to the right. However, even as relocation costs approach zero, relocation does not necessarily arise for all parameters.

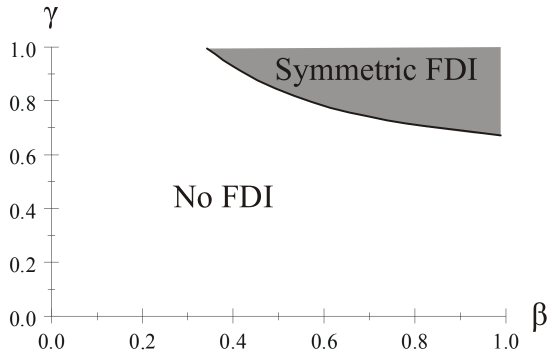

Figure 2: FDI without offshoring possibilities (F=0.2)

5.2.2 Offshoring

Suppose relocation is possible ($R = 0.5$). As before, for $F = 1$, No FDI is the only equilibrium. For $F = 0.5$, however, Figure 3 shows that there is asymmetric FDI when intrafirm communication is very good and external spillovers are essential.[19] One firm engages in FDI and offshoring, so as to benefit from external spillovers. It uses the knowledge obtained to increase its monopoly profit abroad. The emergence of FDI thus relies crucially on the existence of the offshoring possibility: As we saw in the preceding subsection, without offshoring possibilities, No FDI is the only equilibrium for $F = 0.5$.

For $F = 0.2$, Figure 4 shows that, in the HRC region, for sufficiently good intrafirm communication and internal R&D, there is symmetric FDI, as in the case without offshoring option. Firms do not gain from offshoring, but they can earn sufficient profits in the foreign location even so. In the LRC region and in the MRC region for sufficiently good intrafirm communication and spillovers, there is asymmetric FDI with offshoring in a large region where there was No FDI without the offshoring option.[20]

For $F = 0.1$, Figure 5 shows that, in regime HRC, for sufficiently good internal R&D (β high) and intrafirm communication (γ high), there is no

[19] Here and in the following figures, dashed lines describe regime boundaries in the offshoring game.

[20] A much smaller part of the region with asymmetric FDI consists of parameters for which there is symmetric FDI without the offshoring option.

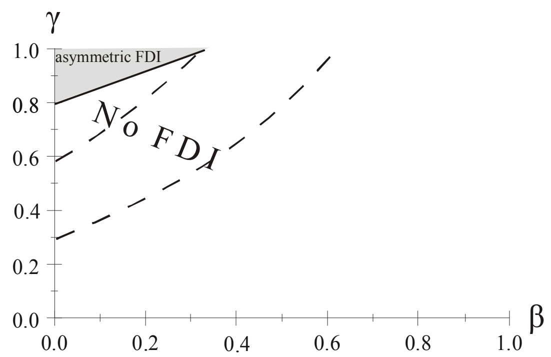

Figure 3: The FDI game with low relocation costs (F=0.5)

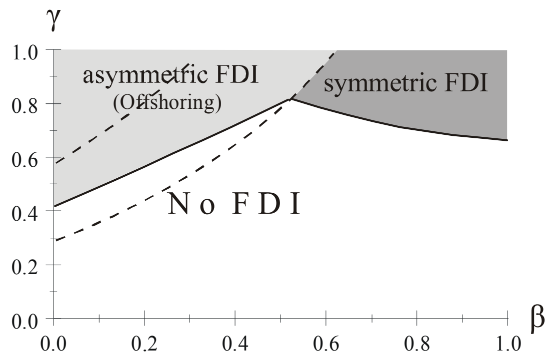

Figure 4: The FDI game with low relocation costs (F=0.2)

FDI. Without the prospect of external spillovers there is not enough to be gained from FDI, because internal technology transfer is not very good. In intermediate ranges, there is symmetric FDI. In most of this region, this is true even though there is no offshoring and thus no benefit from external spillovers. Internal communication is sufficiently well developed that the foreign location can benefit from cost reductions at home. Finally in most of the LRC and MRC regime, there is an asymmetric FDI equilibrium. The prospects of external spillovers lure one firm into the other country.

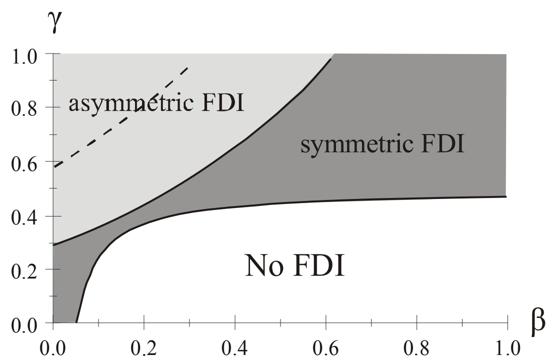

Figure 5: The FDI game with low relocation costs (F=0.1)

5.3 Summary

The analysis reveals that the offshoring option makes FDI more likely: For $F = 0.5$, FDI does not arise without the offshoring possibility, whereas it does for sufficiently low relocation costs. For $F = 0.2$ or $F = 0.1$, the parameter regions with FDI become larger when offshoring is possible, as a comparison of Figure 2 with Figures 4 and 5 shows. Moreover, asymmetric FDI, with only one firm carrying out FDI and offshoring R&D can arise in a symmetric setting. Moreover, both internal and external spillovers can have non-monotone effects on FDI: For instance, for suitable parameter values higher external spillovers (decreases in β) lead from symmetric FDI to No FDI and then to asymmetric FDI (Figure 4).

6 The welfare effects of FDI

The welfare effects of FDI on source countries and recipients have been the subject of considerable debate, and they are often regarded as ambiguous.[21] Based on our analysis, we can obviously not give a complete discussion of this point. First, welfare discussions of offshoring typically put particular em-

[21] See 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.

phasis 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.

Proposition 2 *Suppose $\gamma > \beta$. Further, suppose the equilibrium involves asymmetric FDI and offshoring 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 had invested in FDI. In country 1 the consumer surplus is higher than without FDI, whereas the effect on producer surplus is ambiguous.*

Proof. For an offshoring equilibrium, profits for firm 2 must be higher than in the case without FDI. Thus, a sufficient condition for welfare to increase is that consumer surplus does. As country 2 is served by a monopoly no matter whether offshoring takes place or not, the consumer surplus increases if and only if the costs are lower with offshoring than without. This is true if the cost reduction from external spillovers dominates over the cost increase from having to rely on internal communication, that is, if $\gamma > \beta$. ■

The assumption $\gamma > \beta$ makes sure that the home-country cost reduction from technology sourcing outweighs the losses from intra-firm communication. This guarantees that home-country consumers benefits from lower prices. Of course, even if $\beta \geq \gamma$, welfare may be higher in an asymmetric offshoring equilibrium than in an equilibrium without FDI, provided the producer surplus is much higher in the former case.

7 The impact of market size

The empirical literature suggests that offshoring locations are more likely to emerge in larger markets. We now give theoretical support for this statement, albeit with a qualification. We show that, for certain 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 introduce subscripts S and L for profits in the small and large country, respectively. The following assumption captures the essence of market size:

Assumption 2 *(i) For arbitrary cost constellations, profits are larger in the large country, that is* $\Pi_L^M(.) \geq \Pi_S^M(.)$, $\Pi_L^D(.) \geq \Pi_S^D(.)$.
(ii) For arbitrary cost constellations, profit increases resulting from lower costs are larger in the large country.

We now ask whether an asymmetric FDI equilibrium is more likely to occur in the large country than in the small country. We confine ourselves to the LRC-regime; with $R = 0$. Arguing as in Proposition 1, an Asymmetric FDI Equilibrium in the large country requires

$$\Pi_S^D(\gamma) \leq F, \tag{5}$$
$$F \leq \Pi_L^D(1) + \Pi_S^M(\gamma) - \Pi_S^M(\beta). \tag{6}$$

Condition (5) makes sure that the firm that is located only in the large country does not deviate by adding a plant abroad; inequality (6) guarantees that the firm that carries out FDI and practices R&D-offshoring gains from doing so rather than refraining from FDI. An asymmetric FDI equilibrium in the small country requires

$$\Pi_L^D(\gamma) \leq F, \tag{7}$$
$$F \leq \Pi_S^D(1) + \Pi_L^M(\gamma) - \Pi_L^M(\beta). \tag{8}$$

Clearly, (5) for the large country is easier to satisfy than the corresponding condition (7) for the small country: 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. Hence, the conditions for the asymmetric equilibrium are easier to satisfy when the large country is the research location provided (8) implies (6), that is,

$$\Pi_L^D(1) - \Pi_S^D(1) \geq \Pi_L^M(\gamma) - \Pi_L^M(\beta) - \left(\Pi_S^M(\gamma) - \Pi_S^M(\beta)\right). \tag{9}$$

The left-hand side is always positive, as the firm that carries out FDI and offshore R&D has higher duopoly profits in a large location. If $\beta > \gamma$, the right-hand side is negative. Since it is cheaper to serve the monopoly location with own home country R&D than by sourcing from abroad, there is a second reason why an R&D location in a large country is more robust than in a small country: The losses from not serving the monopoly with local R&D are smaller when the monopoly location is small. Thus (9) holds and offshoring into the large country is more likely.

If $\gamma > \beta$, however, the right-hand side of (9) is also positive by part (ii) of Assumption 2: When the R&D location is large, the offshoring firm benefits less from the positive R&D effects in its (small) home country monopoly. Therefore, the equilibrium conditions are not necessarily easier to satisfy in the large country. Indeed, consider a scenario where product market competition in each market is very strong (e.g., close to homogeneous Bertrand competition) and thus (9) is violated. Then, product market profits in both countries are essentially zero, and thus so is the left-hand side of (9). The right-hand side, however, can be very negative. Intuitively, in this setting, market access is no reason for FDI and offshoring, whereas technology sourcing is. Therefore, compared to an R&D center in a large country, a center in the small country has the advantage that the gains in the monopoly location are larger, and essentially no disadvantage.

8 Related literature

We now discuss the relation between our paper and existing literature. To repeat, the key features of our analysis are as follows.

1. The locations of production and 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.

Our earlier paper (Gersbach and Schmutzler 1999) also treated 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 addressed very different questions.[22]

The most closely related contribution is Belderbos, Lykogianni and Veugelers (2005), henceforth BLV.[23] 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, and BLV do not treat welfare issues. Concerning the possible R&D location decisions, whereas we take one polar case (namely that a firm's R&D can only occur in one location), BLV emphasize the other polar case that R&D is perfectly divisible across 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.

Petit and Sanna-Randaccio (2000) and Norbäck (2001) also analyze the relation between FDI and R&D decisions. Both papers consider the extent of R&D rather than the location as an endogenous variable, and thus our analysis is complementary to these papers. Like our paper, Petit and Sanna-Randaccio (2000) use a two-country two-firm set-up, with each firm initially

[22] In a settingwith intense local competition (Bertrand), we asked there under which circumstances multi-plant firms nevertheless produce in some joint location so as to benefit from technology sourcing. By the very nature of this exercise, the paper requires at least three locations.

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

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. The authors first analyze how locational decisions affect investments, then they consider how location choices depend on parameters such as spillovers. They show that higher spillovers induce a move from FDI to exports.[24] 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. The author considers the effects of higher technology transfer costs, corresponding roughly to worse internal spillovers on the choice between FDI and exporting.

9 Conclusions and extensions

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. Also, if equilibrium behavior gives rise to R&D relocation, it results in higher domestic welfare under fairly general conditions. This contrasts with the popular argument that R&D offshoring reduces domestic welfare.[25]

9.1 Simultaneous decisions

The main insights still hold if the decisions concerning FDI and R&D are carried out simultaneously. Then, each firm has three possible strategies: No FDI, FDI without offshoring and FDI with offshoring. The payoffs for each of the nine resulting strategy profiles can be derived as before. An equilibrium without FDI requires that firms neither deviate to FDI with or

[24] To 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.

[25] See Graham and Krugman (1989), Neven and Siotis (1993) for a discussion.

without offshoring; hence, conditions (3) and (12) in the Appendix have to hold simultaneously. As before, the equilibrium is likely to arise with high fixed costs and relocation costs and with intense product market competition, whereas, with bad intrafirm communication and low R&D-spillovers, similar qualifications arise as in the sequential case. Contrary to the sequential case, however, an asymmetric equilibrium with only one firm carrying out FDI and offshoring cannot exist, except for degenerate cases.

An equilibrium with both firms carrying out FDI and one firm offshoring exists, provided condition (2) holds and, in addition,

$$\Pi^D(\gamma) + \Pi^D(1) \geq \Pi^D(\beta, \beta\gamma) + F + R$$

and

$$\Pi^D(\gamma) \geq F.$$

As in the sequential model, the offshoring equilibrium essentially requires parameters to be opposite than for the No-FDI equilibrium.[26]

9.2 Continuous offshoring decisions

Next, allow firms to move some arbitrary fraction λ_i offshore at a cost $K(\lambda_i)$ as in BLV. For instance, extending our assumptions on cost reductions for $\lambda_i \in \{0,1\}$ linearly to the entire interval $[0,1]$, firm i obtains a cost reduction

$$(1-\lambda_i)(\lambda_j + (1-\lambda_j)\beta) + \gamma(\lambda_i(1-\lambda_j) + \lambda_j\beta)$$

at home and

$$\gamma(1-\lambda_i)(\lambda_j + (1-\lambda_j)\beta) + (\lambda_i(1-\lambda_j) + \lambda_j\beta)$$

abroad. As an example for how offshoring decisions are made in the continuous setting, consider the subgame where only firm 1 has carried out FDI. Thus, it has a monopoly at home and faces a competitor abroad that must have $\lambda_2 = 0$, because it cannot offshore its R&D to foreign locations. Ignoring

[26] The only qualification concerns intra-firm spillovers which again have ambiguous effects on the offshoring equilibrium.

fixed costs of FDI and relocation, payoffs of firm 1 are

$$\Pi^M\left(\left(1-\lambda_1\right)\beta+\gamma\lambda_1\right)+\Pi^D\left(\gamma\left(1-\lambda_1\right)\beta+\lambda_1,\left(1-\lambda_1\right)\beta+\lambda_1\right).$$

Denote the arguments of Π^M as x and of Π^D as x_1 and x_2. Then, the net marginal benefits of offshoring (increasing λ_1) are

$$\left(\gamma-\beta\right)\frac{d\Pi^M}{dx}+\left(1-\beta\gamma\right)\frac{\partial\Pi_1^D}{\partial x_1}+\left(1-\gamma\right)\frac{\partial\Pi_2^D}{\partial x_2}-K'(\lambda_1).$$

This term consists of (i) a cost-effect on the monopoly profit (which is positive if external spillovers are strong and intrafirm communication is good); (ii) a positive effect on own duopoly profits resulting from the fact that own costs in the foreign location are lower with more offshoring, (iii) a negative effect on duopoly profits resulting from the fact that the competitor also benefits from external spillovers, and (iv) marginal relocation costs. The optimal level of relocation is obtained by setting the net marginal benefit of relocation equal to zero. The analysis for the case where both firms carry out FDI is similar. In this fashion, one can obtain general comparative-statics condition for R&D. For the Cournot model and particular specifications of the relocation costs, different FDI/RDI constellations can be obtained.

10 Appendix: Equilibria for MRC and HRC

We now summarize the equilibrium structure in regime MRC.

Remark 3: *In regime MRC:*
(i) A No-FDI equilibrium exists if and only if

$$\Pi^M(\beta) \geq \Pi^M(\gamma) + \Pi^D(1) - F - R. \tag{10}$$

(ii) A Symmetric FDI equilibrium exists if and only if

$$\Pi^D(\beta, \beta\gamma) + \Pi^D(\beta\gamma, \beta) - F \geq \Pi^D(1). \tag{11}$$

(iii) An Asymmetric FDI equilibrium exists if and only if (10) and (11) hold with signs reversed.

Intuitively, condition (10) 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 in MRC. (11) guarantees that the investing firm does not want to deviate by not investing.

The equilibrium structure in regime HRC is summarized as follows.

Remark 4: *In regime HRC:*
(i) A No-FDI equilibrium exists if and only if

$$0 \geq \Pi^D(\beta\gamma, \beta) - F. \tag{12}$$

(ii) A Symmetric FDI equilibrium exists if and only if

$$\Pi^D(\beta\gamma, \beta) - F \geq 0. \tag{13}$$

Intuitively, as there can be no R&D offshoring on the equilibrium path or in any deviation subgame, firms earn $\Pi^D(\beta\gamma, \beta) - F$ in an FDI location. Thus, carrying out FDI is worthwhile if and only if $\Pi^D(\beta\gamma, \beta) > F$.[27]

[27] In the degenerate case that $\Pi^D(\beta\gamma, \beta) = F$, there is an asymmetric FDI equilibrium that is not strict.

11 References

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