Localized spillovers and foreign direct investment: a dynamic analysis

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Localized spillovers and foreign direct investment: a dynamic analysis

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Abstract

It has been empirically shown that firms invest in foreign countries also with the aim to absorb technological knowledge. However, the recent literature on technological innovation and foreign expansion has not fully taken into account these features of foreign direct investment. Introducing this new element into the analysis implies assuming that multinationals and exporters operate with different degrees of technological spillovers. Our aim is to study how these differences in the transmission of knowledge may affect the firms' incentive to innovate and their behaviour in an international market, that is their choice between serving foreign markets via exports or foreign investment.

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Keywords: R&D, innovation, geographical location, international strategy, multinational enterprise.

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1 Introduction

The acceleration of firms international expansion via foreign direct investment (FDI) is one of the major causes of the rapid transformation of the world economy in recent years. Figures concerning the years 1985-1996 show that FDI grew twice as much as world trade during that period (UNCTAD-DTCI, 1997). Another interesting point is that FDI among developed countries still accounts for the bulk of world FDI flows: during the years 1990-95 developed countries accounted for 90.5% of world FDI outflows and 67% of world inflows (UNCTAD-DTCI, 1996). The traditional view that FDI flows to developing countries because of low costs of labour and/or capital is therefore being denied by empirical data.

Different reasons may push the firms towards multinational expansion like, for example, location near sources of technological innovation: firms tend to concentrate in regions (national or foreign) where the industry is characterized by strong technological externalities (see, e.g. Grunfeld, 1999). In fact, it is empirically shown (Neven and Siotis (1996), Fors (1998)) that firms may invest abroad with the aim to absorb technological knowledge. This is what is called "technology sourcing through FDI". On the other hand, Dunning (1997), studying 150 of the world’s largest industrial enterprises, finds that FDI is likely to generate a greater feedback of technological knowledge than shallower forms of international involvement such as export or subcontracting. This may imply that local firms will also take advantage of the closer location of a multinational firm (MNE), absorbing more quickly the technological knowledge produced by the latter.

The recent literature on technological innovation and foreign expansion has not fully taken into account these features of FDI, apart from the above mentioned empirical studies. A few exceptions are the recent papers by Grunfeld (1999), Fosfuri and Motta (1999) and Siotis (1999) who discuss how localized spillovers may affect the firm’s decision of how to serve a foreign market. These models, however - differently from the one presented here - are described in a static setting, and the amount of R&D undertaken by the firms is considered as exogenous.

Introducing this "location" element into the analysis implies assuming that MNEs and exporters operate with different degrees of technological spillovers. We shall assume in what follows that the degree of transmission of technological knowledge is higher between a local firm and a MNE producing the same good in that country (in both ways) than between a local firm and a foreign firm exporting the same good to that country. This makes sense as vicinity increases the degree of knowledge transmission. Technological spillovers in our set-up are therefore dependent on the mode chosen by the firms to serve the foreign market, and, therefore, are no longer symmetric. This assumption is here incorporated into a dynamic oligopoly model in which both the firms’ mode of foreign expansion
and R&D levels are endogenously determined.

We build a two-country model with two firms - one from each country - producing a homogeneous good. We assume process innovation, where the cost reducing technological innovations are the outcome of the firm’s accumulated R&D. Each firm must take three different types of decisions: (i) the mode of foreign expansion (ii) how much to invest in R&D, (iii) how much to sell in each market (country). In particular, as regards point (i), each firm must decide among two possible strategies: export - EXP - (producing in the home country and exporting abroad), foreign direct investment - FDI - (producing in both countries thus becoming a MNE).\(^1\)

Three different situations are thus described: a MNE duopoly, a exporting duopoly, a mixed duopoly (i.e. a MNE and a exporting-firm duopoly).

Equilibrium strategies concerning the mode of foreign expansion are obtained by applying a long-run investment selection approach, since the choice for the firms to become MNEs implies undertaking a foreign direct investment by establishing a new plant in the foreign country. That is we extend capital budgeting analysis to the framework of a duopolistic market. Equilibrium solutions for sales and investment in R&D are obtained by computing Markov equilibrium strategies. Firms decide first the mode of foreign expansion, then they choose how much to invest in R&D and how much to produce and sell in each market. The final structure of the market is therefore endogenously determined by the model.

The dynamic game model considered in this paper is non-linear. The analysis employs analytical tools whenever possible and numerical simulations otherwise. The numerical results are obtained by means of an algorithm based on a modified policy iteration method that is capable of computing Markov equilibria for some non-linear dynamic games outside the standard linear-quadratic formulation (see Appendix). In what follows, we shall often refer the reader to Petit, Sanna-Randaccio and Tolwinski (2000) (from now on P-SR-T, 2000). This study, being based on the assumption that the intensity of technological spillovers was not affected by the location of production, will be widely employed as a benchmark in this paper\(^2\). The model has been framed in order to account for the most important features of firms’ internationalization in the 1990s. That is we consider FDI flows between industrialized countries and therefore our model describes two identical countries and considers horizontal FDI. Asymmetries derive only from different degrees of technological spillovers, depending on the mode of foreign expansion. This allows us to focus on the main topic of the paper, that is on the

\(^1\)A third strategy, that is no expansion abroad, could easily be introduced, giving rise to two monopolistic situations when one of the firms chooses that strategy (see Petit et al. 2000). However, we preferred to eliminate this possibility so as to avoid unnecessary complications. It can be shown that the essence of the results is independent of this assumption.

\(^2\)See also Sanna Randaccio (2002) for some welfare implications of localized versus non-localized spillovers.
impact that asymmetries in the degree of transmission of knowledge - due to differences in location - may have on the incentive to innovate and on the behaviour of firms operating in an international setting, that is on the choice of whether to serve a foreign market via export or FDI, and therefore on the resulting equilibrium market structure. In this framework, we also investigate whether the possibility to absorb higher knowledge is really an incentive for firms to invest abroad.

The paper is organized as follows. In section 2 we present the model and derive equilibrium solutions for sales and R&D investments. Section 3 describes the assumptions on technological spillovers between the firms. Some numerical results are provided in section 4. Section 5 presents the main conclusions.

2 The Model

The dynamic model is described in discrete time. We consider two countries (country I and II) and two firms, firm 1 and 2, which manufacture the same homogeneous good in country I and II respectively. On the demand side we consider a nonlinear stationary inverse demand function of the constant elasticity type, i.e.

\[ p_I(q_{1,I}, q_{2,I}) = A_I(q_{1,I} + q_{2,I})^{-\beta_I} \quad p_{II}(q_{1,II}, q_{2,II}) = A_{II}(q_{1,II} + q_{2,II})^{-\beta_{II}} \]  

(1)

where \( p_I \) and \( p_{II} \) represent prices in country I and II respectively, and \( q_{i,k} \) represents the sales of firm \( i \) in country \( k \) (\( i = 1, 2, \ k = I, II \)). The parameters \( A_I, A_{II}, \beta_I \) and \( \beta_{II} \) are positive constants, with \( \beta_I = 1/B_I \) and \( \beta_{II} = 1/B_{II} \), where \( B_I, B_{II} \) are demand elasticities in countries I and II respectively.

Learning resulting from investment in R&D characterizes the production process, implying that marginal and unit costs decrease as cumulative investment in R&D increases. That is, we consider process innovations that result in reductions in production costs. R&D investment is here modelled as a centralized activity which is carried out only in the home country of each firm. In other words, we assume that research activity is undertaken only by the parent firm. Therefore, if a firm has a subsidiary abroad production would be the only activity of the subsidiary.

Let \( w_{it} \geq 0 \) be the cumulative technological knowledge produced by firm \( i \), resulting from (and represented by) R&D capital accumulation, i.e., the R&D capital accumulated by firm \( i \) from time 0 up to time \( t \). Firm \( i \)'s current rate of investment in R&D is denoted by \( u_{it} \). The state variable \( w_{it} \) is, therefore, related to the decision variable \( u_{it} \) through the state equation

\[ w_{it+1} = (1 - \mu)w_{it} + u_{it} \quad (i = 1, 2) \]

(2)
where \( \mu \in (0,1) \) is the rate of depreciation of R&D capital (i.e. of the accumulated technological knowledge produced by firm \( i \)).

Since we allow for the possibility of imperfect appropriability (technological spillovers between the firms), we introduce a spillover parameter \( \alpha_i \in [0,1] \). This means that the level of technological knowledge of firm \( i \) at each time \( t \) is given by its own accumulated technological knowledge up to \( t \) and by a fraction \( \alpha_i \) of the knowledge accumulated by the other firm, i.e. \( w_{it} + \alpha_i w_{jt} \) \( (i,j = 1, 2; i \neq j) \).

In our set-up the spillover parameter \( \alpha_i \) represents therefore an incoming spillover. In what follows we shall refer to the above expression \( (w_{it} + \alpha_i w_{jt}) \) as the firm’s "knowledge" or "effective research".

Let \( c_i(w) \) denote firm \( i \)'s marginal (variable unit) cost per period, corresponding to the level of R&D capital \( w \) where \( w = (w_1, w_2) \). As indicated above, \( c_i \) will be assumed to decrease as technological knowledge grows. The magnitude of firm \( i \)'s cost reduction at any time \( t \) is determined according to the expression\(^3\)

\[
c_i(w) = c_i^0 (1 + w_i + \alpha_i w_j)^{-\theta_i} \tag{3}
\]

\( i = 1, 2 \), where \( c_i^0 \) is the initial variable unit cost of firm \( i \).

The parameter \( \theta_i \), the rate of innovation, determines the rate at which the unit (variable) costs decline with accumulated knowledge from their initial level \( c_i^0 \). Under stationary equilibria, the accumulated R&D capital \( w_i \) will, in the long term, approach a steady state level, say \( \hat{w}_i \); therefore the lowest unit variable cost that a firm can reach by investing in R&D will equal \( c_i^0 (1 + \hat{w}_i + \alpha_i \hat{w}_j)^{-\theta_i} \).

Besides variable costs, each firm incurs an exogenous firm-specific fixed cost \( f \) in each period and a plant-specific fixed cost \( G \). The parameter \( f \) captures the cost of some firm-specific activities such as advertising, marketing, distribution and managerial services, while \( G \) is the cost of building a plant. The existence of fixed costs (both firm and plant specific) implies that the production process presents economies of scale: firm economies of scale and plant economies of scale.

In order to serve the foreign country, each firm can choose between export and FDI. Export leads to additional marginal (and unit) transport cost \( s \)\(^4\). FDI, on the other hand, involves establishing a new plant in the other country, with additional plant specific fixed cost \( G \). Therefore, a multinational will incur the cost of having two plants \( (2G) \), while an exporter will have the cost of only one plant\(^5\).

Profits of the two firms will differ depending on the mode of foreign expansion. That is

\(^3\)See Petit and Tolwinski (1999) for a similar specification.

\(^4\)The parameter \( s \) may capture also some forms of policy induced discrimination. In fact a unit tariff, or some types of non-tariff barriers (as in Sanna-Randaccio (1996)), may be incorporated in the model as an increase in the value of \( s \).

\(^5\)Since we consider two markets of similar dimensions, we assume that the cost of a plant will be the same in both countries. We also assume that \( G \) is a sunk cost.
1. **MNE duopoly.** Both firms undertake FDI to create a production subsidiary in the other country, i.e. become MNEs. Profits are then given by

\[
\pi_{1,2}^{DD} = \sum_{t=0}^{\infty} \rho^t h_{1,2}^{DD}(w_{1t}, w_{2t}, q_{1,t}, q_{2,t}, q_{1,II}, q_{2,II}, u_{1,2}, I_{1,2}) - 2G
\]  

where \(\rho \in (0, 1)\) denotes a discount factor, the superscript DD stands for MNE-duopoly and

\[
h_{1,2}^{DD}(\ldots) = A_I(q_{1,I} + q_{2,I})^{-\beta_I} q_{1,I} + A_{II}(q_{1,II} + q_{2,II})^{-\beta_{II}} q_{1,II} - c_1^0(1 + w_I + \alpha_1^{DD} w_{2j})^{-\theta_1} (q_{1,I} + q_{2,I}) - u_I - (1/2) \gamma u_{1,2}^2 - f
\]  
i = 1, 2, \quad i \neq j,

\(h^D(\ldots)\) is a stationary function. The cost of investment in R\&D is given by \(u + (1/2) \gamma u^2\), \(\gamma > 0\), where the quadratic term indicates the possibility of diminishing returns to R\&D investments (see, e.g., Cheng 1984).

2. **Exporting duopoly.** Both firms have only one plant and export to the other country. Profits are then given by:

\[
\pi_{1,2}^{EE} = \sum_{t=0}^{\infty} \rho^t h_{1,2}^{EE}(w_{1t}, w_{2t}, q_{1,t}, q_{2,t}, q_{1,II}, q_{2,II}, u_{1,2}, I_{1,2}) - G
\]

where

\[
h_{1,2}^{EE}(\ldots) = A_I(q_{1,I} + q_{2,I})^{-\beta_I} q_{1,I} + A_{II}(q_{1,II} + q_{2,II})^{-\beta_{II}} q_{1,II} - c_1^0(1 + w_I + \alpha_1^{EE} w_{2j})^{-\theta_1} (q_{1,I} + q_{2,I}) - u_I - (1/2) \gamma u_{1,2}^2 - f
\]  

and

\[
\pi_{1,2}^{EE} = \sum_{t=0}^{\infty} \rho^t h_{1,2}^{EE}(w_{1t}, w_{2t}, q_{1,t}, q_{2,t}, q_{1,II}, q_{2,II}, u_{1,2}, I_{1,2}) - G
\]

where

\[
h_{1,2}^{EE}(\ldots) = A_I(q_{1,I} + q_{2,I})^{-\beta_I} q_{2,I} + A_{II}(q_{1,II} + q_{2,II})^{-\beta_{II}} q_{2,II} - c_2^0(1 + w_I + \alpha_2^{EE} w_{1j})^{-\theta_2} (q_{2,I} + q_{2,II}) - u_2 - (1/2) \gamma u_{1,2}^2 - f
\]

where the superscript EE stands for exporting duopoly.
3. Mixed duopoly: a MNE and a exporting firm. One firm serves the other country by creating a new plant and the other firm by exporting. Assuming firm 1 to be the exporting firm and firm 2 the MNE (the so-called the ED-duopoly), discounted profits are given by:

$$\pi_1^{ED} = \sum_{t=0}^{\infty} \rho^t h_1^{ED}(w_{1t}, w_{2t}, q_{1,It}, q_{2,It}, q_{1,II_t}, q_{2,II_t}, u_{1,t}) - G$$  

(10)

where

$$h_1^{ED}(\ldots) = A_I(q_{1,I} + q_{2,I})^{-\beta_I} q_{1,I} + A_{II}(q_{1,II} + q_{2,II})^{-\beta_{II}} q_{1,II}$$

$$-c_1^0(1 + w_1 + \alpha_1^{ED} w_2)^{-\theta_1} q_{1,I} - (c_1^0(1 + w_1 + \alpha_1^{ED} w_2)^{-\theta_1} + s)q_{1,II} - u_1 - (1/2) \gamma u_1^2 - f$$  

(11)

and

$$\pi_2^{ED} = \sum_{t=0}^{\infty} \rho^t h_2^{ED}(w_{1t}, w_{2t}, q_{1,It}, q_{2,It}, q_{1,II_t}, q_{2,II_t}, u_{2,t}) - 2G$$  

(12)

where

$$h_2^{ED}(\ldots) = A_I(q_{1,I} + q_{2,I})^{-\beta_I} q_{2,I} + A_{II}(q_{1,II} + q_{2,II})^{-\beta_{II}} q_{2,II}$$

$$-c_2^0(1 + w_2 + \alpha_2^{ED} w_1)^{-\theta_2} (q_{2,I} + q_{2,II}) - u_2 - (1/2) \gamma u_2^2 - f$$  

(13)

As mentioned above, the parameter $\alpha_i$ is defined in the range $0 \leq \alpha_i \leq 1$. The case of no spillovers ($\alpha_i = 0$) is obviously an extreme case of complete intellectual protection. More frequently, however, involuntary information leaks may occur, as empirical research shows

6Empirical research shows in fact that rival firms normally learn about technical characteristics of new products and processes within twelve months from their introduction. See e.g. Mansfield (1985).

In this paper we assume that the transmission of technology increases with proximity, that is a firm learns more from other firms the lower is the geographical distance between them. Therefore, the transfer of technology between the two firms is stronger when firms build a plant in the foreign country, that is when they become multinationals. This creates an asymmetry related to the mode of foreign expansion, which explains why $\alpha_i$ can be different in each state: DD, EE or ED. The assumptions concerning the different values assigned to the spillover parameter $\alpha_i$ are illustrated in section 3.

As mentioned in the Introduction, each firm must take three different types of decisions: (i) the mode of foreign expansion (ii) how much to invest in R&D, (iii) how much to sell in each market (country). The dynamic nature of the model gives rise to a dynamic game between the two firms. For the sake of analytical simplicity, the game is solved in three steps (see also P-SR-T,2000).
At the first stage we compute equilibrium strategies for sales (for each market configuration considered), where the levels of sales are expressed as functions of the R&D accumulated capital of both firms (i.e. the state variables)\(^7\).

Each firm \(i\) chooses its level of sales at home and abroad (and thus its level of output), so as to maximize its respective profit function under the Cournot assumption. Equilibrium strategies for sales will be sought in the class of the so-called Markov equilibrium strategies associating non-negative levels of sales \(q_{i,k}\) with non-negative values of the R&D capital accumulated by both firms \(w = (w_1, w_2)\), i.e. \(q_{i,k} = \varphi_{i,k}(w)\) \((i = 1, 2; k = I, II)\). The specific form of these equilibrium strategies is described in Appendix A\(^8\).

In order to find the equilibrium strategies for investment in R&D we need to substitute into the firms’ profit functions the equilibrium strategies for sales just described. This produces new optimization problems, where the objective function of each firm depends only on its rate of investment \((u_i)\) and on the accumulated capital in R&D of both firms \((w_1, w_2)\). Again, we shall consider only the case of a MNE duopoly. The equilibrium solutions for investment in R&D for a exporting duopoly and a mixed duopoly can be obtained similarly.

The firms choose their investment rates \(u_{it}\) independently, by maximizing total discounted profits. The new form of firm \(i\)’s profit function is then

\[
\pi_i^{DD} = \sum_{t=0}^{\infty} \rho^t \tilde{h}_i^{DD}(w_{1t}, w_{2t}, u_{it}) - 2G
\]  

where

\[
\tilde{h}_i^{DD}(w_1, w_2, u_i) = NR_i^{DD} + NR_{II}^{DD} - u_i - \frac{1}{2} \gamma_i u_i^2 - f
\]  

and where \(NR_{II}^{DD}\) and \(NR_{II}^{DD}\) - which represent the revenues, net of production costs, of firm \(i\) in countries \(I\) and \(II\) respectively \((i = 1, 2)\) - are described in Appendix B.

As mentioned before, the state variables evolve according to Eq.(2).

The problem here defined is therefore a dynamic game with R&D investment rates \((u_{it})\) as decision variables. To solve this game we compute Markov equilibrium strategies, \(\psi_i(w)\), associating non-negative investment rates with the values of accumulated R&D capital \(w = (w_1, w_2)\). The problem has

\(^7\)We will henceforth solve the model taking into account only the case in which both firms expand abroad via direct investments (the DD case). The analytical description concerning the case in which both firms expand abroad via exports (the EE case) and the case in which one firm expands abroad via exports and the other via FDI (the ED case) are omitted for lack of space but are available from the authors upon request.

\(^8\)Therefore nothing can be said about the time trajectory of the levels of sales (and prices) till the values of the state variables \(w_{it}\) at each \(t\) are known.
been solved numerically by means of a computational algorithm based on a modified policy iteration technique (see Appendix C). This method is based on the Dynamic Programming Principle, i.e.:

A strategy pair \( \psi^*(w) = (\psi_1^*(w), \psi_2^*(w)) \) is a Markov (perfect) equilibrium for the dynamic game at hand if there exist functions \( V_i(w) \), for \( i = 1, 2 \), such that:

\[
V_1(w) = \max_{u_1} \{ h_1(w, u_1) + \delta V_1(f(w, u_1, \psi_2^*(w))) \}
\]

and

\[
V_2(w) = \max_{u_2} \{ h_2(w, u_2) + \delta V_2(f(w, \psi_1^*(w), u_2)) \}
\]

where \( h_i(w, u_i), \ i = 1, 2 \), is defined as in Eq. (15) and where

\[
f(w, u_1, u_2) = [(1 - \mu)w_1 + u_1, (1 - \mu)w_2 + u_2]^T
\]

The computation of a Markov equilibrium of the duopoly problem is equivalent to solving the above equations.

Finally, once Markov equilibrium strategies for R&D investments have been obtained, we analyze the equilibrium market structure which is the result of the decisions taken by the firms on the mode of foreign expansion. That is, we compute the Nash equilibrium (equilibria) of the matrix game described in Table 1, where the payoffs are the discounted profits of each duopolist, as defined above.

It should be pointed out that the underlying assumption in our model is that firms decide whether to make or not an investment abroad (i.e. to become MNEs or exporters) by applying capital budgeting analysis, that is by considering the present value of the future net cash flows corresponding to the two alternatives, where net cash flows are here approximated by profits for simplicity (see, e.g. Mansfield 1993, Chaps. 1 and 14). Unlike traditional long-run investment planning theory which implicitly suggests that firms act as monopolists when taking their investment decisions, we assume that firms are aware of acting in a duopolistic market, and that, therefore, investment equilibrium strategies must be the result of a game between them\(^9\).

A selection of numerical results is presented in section 4.

\(^9\)Since firms might be willing to reconsider their decisions on the mode of foreign expansion after given periods of time, this possibility can be examined by re-computing equilibrium strategies at different time intervals. We here omit this possibility in order to avoid further complications. The interested reader is referred to P-SR-T, 2000.
<table>
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<th>firm 1</th>
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<td>FDI</td>
<td>$\pi_1^{DE}$, $\pi_2^{DE}$</td>
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Table 1: A matrix game for the determination of equilibrium market structures.