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ABSTRACT

Multinational Knowledge Spillovers with Centralized versus Decentralized R&D: A Game-Theoretic Approach*

This Paper provides a theoretical model on the trade-offs an MNE faces when assigning subsidiaries an active role in innovation and organizing its R&D decentralized versus centralized. R&D decentralization avoids having to adapt centrally developed innovations to local markets, being able to use the specific know-how of the subsidiary. In addition R&D subsidiaries can be used to source locally available external know-how. But the MNE has to organize the transfer of local know-how internally so as to be able to benefit from this location specific know-how throughout the organization. At the same time, decentralization of R&D to the subsidiary level intensifies the challenge of effectively appropriating core technology know-how, preventing the spilling over of valuable know-how to competitors, located in the foreign markets. While R&D decentralization has repercussions on both intra-company technology transfers as well as inter-company technology spillovers, it emerges as a possible equilibrium outcome from the resulting strategic interaction between the foreign subsidiary and local competition. The proposed model treats both internal and external spillovers in a game-theoretic context explicitly recognizing that absorptive capacity is required to be able to use external spillovers. The analysis suggests that a strong local know-how base is not a univocally positive factor for locating R&D abroad and indicates the critical complementary role of managing internal and external spillovers to capitalize on the benefits from R&D decentralization. It also shows that the intensity of product market competition in the host country is important, especially in determining the outgoing spillover costs.

JEL Classification: D21, F23, L16 and O23
Keywords: MNEs, R&D decentralization and technological spillovers

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Multinational knowledge spillovers with centralized versus decentralized R&D : a game theoretic approach

1. Introduction

In the traditional literature on multinationals, following the seminal work of Dunning (1988), multinational activities originate out of the R&D activities of the firm. But rather than seeing the geographic dispersion of MNEs as a *result* of knowledge creation, the emphasis in the literature has shifted towards seeing the geographic dispersion of MNEs as a *source* for knowledge creation (see a.o. Cantwell (1995), Niosi (1999), Kuemmerle (1997)). In the current international environment innovation strategies require increasingly more global sourcing, sensing new market and technology trends worldwide. All this implies a different role for subsidiaries in the innovative strategy of the multinational enterprise, who become important to access (local) external sources. The subsidiary is being viewed as a vehicle to continually reassess and upgrade know-how on core products and technologies, to provide a basis for new generations of innovative products, which can be used throughout the multinational organisation A major challenge identified for the MNE is to find an organisational system that is capable of transferring know-how across units and locations, allowing locally generated know-how to be used globally.

This paper provides a theoretical model on the trade-offs a MNE faces when assigning subsidiaries an active role in innovation and organising its R&D decentralized versus centralized. The model considers R&D decentralization as a choice which allows to use the specific know-how of the subsidiary and avoids having to adapt centrally developed innovations to local markets. In addition R&D subsidiaries can be used to source locally available external know-how. But the MNE has to organize the transfer of local know-how internally so as to be able to benefit from this location specific know-how throughout the organisation. At the same time, decentralization of R&D to the subsidiary level intensifies the challenge of effectively appropriating core technology know-how, preventing the spilling over of valuable know-how to competitors, located in the foreign markets. While R&D decentralization has repercussions on both intra-company as well as inter company technology transfers, it emerges as a possible equilibrium outcome from the resulting strategic interaction between the foreign subsidiary and local competition. The proposed model focuses on how the interplay of internal and external knowledge flows interacts with the nature of host market competition to influence the choice of MNEs to effectively disperse internationally its R&D. It treats both internal and external spillovers in a game-theoretic context explictly recognizing that absorptive capacity is required to be able to use external spillovers.

Abstracting from internal technology transfers, the impact of external know-how spillovers on the incentives of firms to innovate has been widely studied in Industrial Organization (see De Bondt (1996) for an overview). This literature focuses on the importance of the strategic effects of spillovers, stressing the interaction with product market competition. High spillovers can thus lead to underinvestment in R&D, when firms are marketing substitute products. Recently, some I.O. models have taken into account that firms can manage these spillovers through organizational decisions. Cohen and Levinthal (1989) pioneered the idea that firms can try to increase incoming spillovers by investing in "absorptive capacity", i.e. spillovers are more efficient in reducing own costs when the firm is engaged in own R&D. This notion of absorptive capacity has been integrated in the I.O. models on R&D cooperation by Kamien & Zang (2000). The influence of external R&D spillovers on the incentive to engage in FDI has also been analyzed (Petit & Sanna-Randaccio (2000)).

Another related line of research is the geographical localisation of innovative activities. Innovative activities are found to be highly clustered (Jaffe et al (1993), Audretsch & Feldman (1996)). The principle explanatory factor for clustering revolves around the existence of knowledge spillovers. Since distance hinders the exchange of especially tacit knowledge, proximity matters for being able to absorb external spillovers. Hence firms agglomerate their R&D activities to be able to capitalize on external knowledge spillovers. Gersbach & Schmutzler (1999) present a game-theoretic model of geographic clustering of activities. A duopoly decides on the location of their R&D and production, while competing in final output markets à la Bertrand. An agglomeration equilibrium where both firms would choose their R&D site in the same location, requires simultaneously internal and external spillovers: not only must firms learn something from each other in agglomeration, they must also be able to transport this know-how internally. [1]

A more closely related line of previous research, linking internal and external knowledge flows and subsidiaries of MNEs, can be found in Das (1987), who examines whether parent firms will transfer technology to subsidiaries given that local rivals may learn. This model is specifically set up for developing countries: the subsidiary is non R&D active, but receives a transfer of technology from its parents, while it is competing as a

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[1] Gersbach & Schmutzler (1999) consider two types of external spillovers: external spillovers when rival production units are co-localized with own R&D sites, and knowledge complementarities among co-localized R&D sites. In addition, the firms also need to consider that internal spillovers are required when R&D is located separately from production. When interpreting their results in an FDI setting (see Gersbach & Schmutzler (2000)), their restriction to the use of only one R&D site per firm precludes a

leading firm facing a competitive fringe of local firms which are non R&D active but can costlessly learn from subsidiaries. The paper finds that despite learning by local firms, it is still worthwhile for the parent to transfer the better technology. A similar LDC setting is used in Wang & Blomström (1992) who take into account that MNEs face a cost of transferring internally technology, which will be higher for state-of-the-art technologies, and that locals face a cost of learning. When the subsidiary competes in a differentiated duopoly with the local firm who faces a technology gap, they find that technology transfers via FDI are positively related to the level of host country's firms learning investment. The focus of this literature on LDCs implies that only the internal transfers from headquarters to subsidiaries and the external transfers from subsidiaries to local firms are considered, while the competitive structure the subsidiary is facing is one of a weaker local rival. The issue of R&D decentralization is not at stake here.

With the majority of FDI located in developed countries, subsidiaries active in R&D activities and technology sourcing becomes an important issue resulting in flows from local external sources to subsidiaries, while the MNE has to ensure that the locally generated know-how flows from the subsidiary towards the central level. In addition the issue of appropriating know-how becomes more critical when local rivals are no technology laggards. Our analysis of R&D decentralization by the MNE focuses on the interaction between host product market competition and both inter- and intra-firm know-how transfers. We consider both the two-way internal transfer of know-how between headquarters and subsidiaries as well as the two-way external transfer of know-how between subsidiaries and local competitors.

Before presenting the model set-up and results, the paper starts with an overview of recent literature and stylized evidence on internationalization of R&D, which is used when constructing the model.

2. Evidence on R&D decentralization by MNEs

Centrifugal demand and supply related forces for decentralization need to be traded against centripetal forces (see Grandstrand et al (1992)). A *decentralized R&D* allows for responsiveness to local differences. These are the demand oriented motives for decentralization of R&D, where it is important to be close to "lead users" and adapt products and processes to local conditions, often related to host market regulations. Supply oriented motives for R&D decentralization relate to acquiring access to a wider range of scientific and technological skills when technology sourcing (Kogut and Chang (1991)). A *centralized R&D* function allows to capitalize on economies of scale when pooling R&D resources. The result

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treatment of the issue of decentralizing R&D to the subsidiary level with consequent internal know-how is internal transfers of know-how from central R&D labs to subsidiaries (Teece (1976)). In addition centralization allows to better control R&D, minimizing leaking of information to (potential) competitors.

Statistical evidence and survey results on *R&D internationalization* suggest that most research still remains at corporate headquarters (e.g. Patel & Pavitt (1992)). But the percentage of R&D carried out abroad is increasing rapidly (Grandstrand et al (1992), Caves (1996), Serapio & Dalton (1999), Reger (2001)).

If technology sourcing is an (increasingly more) important motive for decentralizing R&D this should be reflected in *technology transfers from local sources to foreign subsidiaries*. Most of the empirical literature on technology spillovers uses patent information to trace know-how flows. Almeida (1996) using US patent citations counts on a sample of foreign subsidiaries in the US semiconductor industry, finds foreign subsidiaries to cite regionally located firms significantly more. Frost (1998) finds proximity matters since foreign subsidiaries cited other entities located in the same state more frequently. Also Branstetter (2000) found Japanese firms investing in the US to have a significantly higher probability of citing other US firms' patents.

But foreign subsidiaries not only acquire local know-how, they are also sources of *knowledge spillovers to the local economy*. The empirical evidence on spillover benefits to the local economy from FDI at the aggregate level, have generally failed to find robust evidence of positive knowledge spillovers from multinational investment (see Blomström & Kokko (1998), Mohnen (2001) for a review). Turning to firm level evidence for spillovers from foreign subsidiaries to the local economy, Almeida (1996) finds that patents belonging to foreign firms investing in the US are cited more by local US firms than other foreign firms. Also Branstetter (2000) finds a higher probability of US firms citing Japanese firms when they invest in the US.

The choice between centralizing and decentralizing R&D also has implications on the *internal know-how flows between parents and subsidiaries*. While for centrally developed innovations, know-how flows from parents to subsidiaries, when subsidiaries are assigned a role in accessing and developing local specific know-how, this know-how needs to flow to corporate level. Recent studies can more easily provide evidence for the transfers of know-how from parents to affiliates, but find less conclusive support for the reverse direction, from subsidiaries to headquarters. Frost (1998), using USPTO data for 1980-1990, found evidence for the importance of headquarter patents for the innovations of subsidiaries, while patent data provided only limited evidence for the transfer of know-how from subsidiaries to headquarters.

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transfers.

Typically most empirical studies who trace know-how flows rely on patent citations. But a vast amount of information is transferred without writing it down in patent application or even in formal contracts, certainly in case of internal transfers. Using survey based evidence to directly assess the occurrence of internal technology transfers between parents and subsidiaries as well as between subsidiaries and other external local partners, Mansfield & Romeo (1980)) found that two third of UK firms indicated that their technological capabilities were raised by technology transfers from US firms to their overseas subsidiaries. But only 20% felt this effect was of importance. Veugelers & Cassiman (2002) using survey data from a sample of Belgian innovation active manufacturing firms similarly found evidence for not only technology transfers from parents to subsidiaries and from subsidiary to external local partners, but also for the reciprocal flows of know-how.

3. The Model Set-up

The empirical evidence seems to suggest that the internationalization of R&D and subsidiaries as technology sources have become an important trend. The model follows the empirical evidence on MNE innovative strategies, with subsidiaries located in countries with an own local know-how base and reciprocal intra- and inter-firm knowledge transfers. We consider two countries (country I and II). Country I is the home base of a MNE (firm 1) which is a monopolist in the home market and controls a production subsidiary in country II, where also a local producer (firm 2) operates. The MNE has to decide whether or not to decentralize its R&D activities to the subsidiary.

Both internal and external flows depend on whether the MNE decides to decentralize or not. When the MNE's foreign production plant is active in R&D, it faces reciprocal external know-how flows with the local competition, i.e. the decentralized R&D unit will be able to absorb know-how from the local market. But at the same time the local competition can absorb know-how from the decentralized R&D unit. As Figure 1 illustrates, in case of centralization there are no external flows, i.e. there is no spilling over of MNE know-how to local firms, but likewise no know-how can be sourced by the MNE. With respect to internal flows, these remain unidirectional from parent to subsidiary in case of centralization, while decentralization implies a bi-directional internal flow.

Insert Fig 1 here

The decentralization decision of multinational R&D is studied in a two stage game. In the first stage firm 1 (the MNE) undertakes its R&D location choice taking into account how this decision affects its own and its rival output decision. In the second stage the subsidiary and the local producer –competing à la Cournot-, decide simultaneously how much to produce and sell in country II, while the parent chooses as a monopolist the output to be sold in country I.

3.1. Own R&D resources and internal & external R&D spillovers

Both the MNE and the local firm are engaged in product innovation. Taking a short run perspective, we assume that the total amount of resources devoted to R&D by each firm is fixed. Thus with $\bar{x}_m$ and $\bar{x}_l$ we indicate the given level of *own* R&D resources respectively from the MNE and the local producer. While the local firm produces and innovates only in its home market, the MNE must decide where or not to decentralize its R&D activities.

$$\hat{x}_m^c = \hat{x}_m^d = \bar{x}_m \qquad (1)$$

$$\hat{x}_l^c = \hat{x}_l^d = \bar{x}_l \qquad (2)$$

where superscript *c* represents R&D centralization and *d* R&D decentralization. Note that not only R&D resources are fixed for each firm, but also that the total R&D resources are assumed to be the same in case of centralization or decentralization.

Although the MNE's R&D resources are fixed at the corporate level, the R&D resources individually available to the parent and the subsidiary varies according to the MNE's R&D location decision. The MNE can locate all of its R&D resources $\bar{x}_m$ in country I. This is the case of centralization. Alternatively, it can locate a share α of its total R&D resources in country II assigning an innovative task to the subsidiary, which is the case of R&D decentralization. Thus the own R&D resources of the parent and the subsidiary in the case of R&D centralization are given by:

$$\hat{x}_p^c = \bar{x}_m \qquad (3c)$$

$$\hat{x}_s^c = 0 \qquad (4c)$$

while in the case of R&D decentralization:

$$\hat{x}_p^d = (1-\alpha)\bar{x}_m \qquad (3d)$$

$$\hat{x}_s^d = \alpha\bar{x}_m \qquad (4d)$$

The total *effective* know-how, which each plant can use for product innovation, is not only composed of own R&D resources, but also includes R&D resources of other plants within the same firm or from other firms, at least to the extent that these resources spill over across firm and country boundaries. As to **internal knowledge transfer** between subsidiary and parent, the know-how generated by the MNE in each market is transferred to the other unit. The parameter β^{Ip} indicates the share of know–how produced by the parent which is transferred to the subsidiary. Reciprocally, the parameter β^{Is} indicates the share of know–

how produced by the subsidiary which is transferred to the parent (see Fig. 1). These internal transfers are imperfect, not only because of the costs associated with transferring know-how but also because of the need to adapt transferred know-how. We have

$$\beta^{I} \leq 1 \tag{5i}$$

In the case of β^{Ip}, a parameter value below 1 reflects the classic cost of adapting the centrally developed knowledge in the home lab to host market conditions. These costs arise from the fact that the products and processes developed by the parent need to be modified to satisfy requirements in the host country. The more dissimilar the home and the foreign market, the larger the need for adaptation, i.e. the smaller will be β^{Ip}.

As to **external knowledge transfer** between the MNE and the local competitor, we assume that there is knowledge dissemination only if there is R&D proximity (cf agglomeration literature). This implies that only when the MNE decides to decentralize its R&D, there will be external spillovers with the local competition. These spillovers are two-way. On the one hand will decentralization create the possibility to source local know-how. These are the incoming spillovers β^{Xl}. On the other hand, locating R&D resources to the local market open up these resources for spillovers to the local competitors. These are the outgoing spillovers β^{Xs}.

$$\beta^{X} > 0 \quad \textit{iff} \quad \alpha > 0. \tag{5ii}$$

The assumption of localized spillovers furthermore implies that even if $\alpha > 0$, there is no involuntary transmission to the local firm of the knowledge generated by the parent in country I, that is for $\hat{x}_p^d = (1-\alpha)\bar{x}_m$. Only the decentralized R&D resources are spillover-prone. This implies that the MNE can influence the flow to external local producers through its decentralization decision.

In addition we account for the fact that the extent to which external spillovers are integrated in the own knowledge base depends on the absorption capacity of the receiver. [2] The own R&D resources serve to develop the absorptive capacity of the firm. Thus we have that the external spillovers received from the local firm by the subsidiary is given by $(\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l$. This implies that the MNE can influence the importance of incoming external spillovers through the amount of R&D resources which are decentralized. Similarly, the external spillovers received by the local firm is given by $(\beta^{Xs}\bar{x}_l)\alpha\bar{x}_m$. This implies that the stronger the R&D base of the local competitor, the more important the outgoing external

[2] Note that we only consider absorptive capacity for external spillovers, but ignore it for internal spillovers.

spillover effects will be for the local firm. We impose the restriction that $\beta^{Xl}\alpha\bar{x}_m \leq 1$ and $\beta^{Xs}\bar{x}_l \leq 1$.

Given the previous assumptions, we can now characterize the effective know-how base for each company. This effective know-how base, being a combination of own R&D and of the know-how obtained through internal and external spillovers, represents the amount the firm would have had to invest in research in the absence of spillovers to obtain the same research output. The effective know-how bases of the multinational parent, of the subsidiary and of the local firm in case of R&D centralization are:

$$X_p^c = \bar{x}_m \tag{6c}$$

$$X_s^c = \beta^{\mathrm{Ip}}\bar{x}_m \tag{7c}$$

$$X_l^c = \bar{x}_l \tag{8c}$$

In case of R&D decentralization, the effective know-how bases are :

$$X_p^d = (1-\alpha)\bar{x}_m + \beta^{Is}\alpha\bar{x}_m + \beta^{Is}(\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l \tag{6d}$$

$$X_s^d = \alpha\bar{x}_m + \beta^{Ip}(1-\alpha)\bar{x}_m + (\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l \tag{7d}$$

$$X_l^d = \bar{x}_l + (\beta^{Xs}\bar{x}_l)\alpha\bar{x}_m \tag{8d}$$

3.2. Market competition

We now turn to characterizing the second stage, which is the market competition stage. Linear demand functions are considered in both markets, which are perfectly segmented. While the parent firm is a monopolist in its home market, in the local market its subsidiary competes à la Cournot with the local competitor. Since product innovation is examined, the position of the respective demand curve for each producer depends on its effective know how base. We thus have:

$$p_I = A_I + X_p^k - b_I q_p^k \tag{9}$$

$$p_{II,s} = A_{II} + X_s^k - b_{II}(q_s^k + \varphi\, q_l^k) \tag{10}$$

$$p_{II,l} = A_{II} + X_l^k - b_{II}(q_l^k + \varphi\, q_s^k) \tag{11}$$

with *k=c, d*. The parameter b_I (b_{II}) is inversely related to market size in country I (country II). The parameter φ captures product differentiation. The higher φ the less differentiated the goods produced by the subsidiary and the local firm and thus the more intense is product market competition in country II.

3.3. Firm profits

The MNE profits are given by the sum of profits gained in the two markets. Thus in the case of R&D centralization:

$$\Pi_m^c = \pi_p^c + \pi_s^c \qquad (12c)$$

$$\Pi_l^c = \pi_l^c \qquad (13c)$$

$$\pi_p^c = [A_I + \bar{x}_m - b_I q_p^c - c_p] q_p^c \qquad (14c)$$

$$\pi_s^c = [A_{II} + \beta^{Ip} \bar{x}_m - b_{II}(q_s^c + \varphi\ q_l^c) - c_s] q_s^c \qquad (15c)$$

$$\pi_l^c = [A_{II} + \bar{x}_l - b_{II}(q_l^c + \varphi\ q_s^c) - c_l] q_l^c \qquad (16c)$$

if R&D decentralization:

$$\Pi_m^d = \pi_p^d + \pi_s^d - \frac{\gamma}{2}(\alpha\bar{x}_m)^2 \qquad (12d)$$

$$\Pi_l^d = \pi_l^d \qquad (13d)$$

$$\pi_p^d = [A_I + (1-\alpha)\bar{x}_m + \beta^{Is}\alpha\bar{x}_m + \beta^{Is}(\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l - b_I q_p^d - c_p] q_p^d \qquad (14d)$$

$$\pi_s^d = [A_{II} + \alpha\bar{x}_m + \beta^{Ip}(1-\alpha)\bar{x}_m + (\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l - b_{II}(q_s^d + \varphi\ q_l^d) - c_s] q_s^d \qquad (15d)$$

$$\pi_l^d = [A_{II} + \bar{x}_l + (\beta^{Xs}\bar{x}_l)\alpha\bar{x}_m - b_{II}(q_l^d + \varphi\ q_s^d) - c_l] q_l^d \qquad (16d)$$

The negative $-\frac{\gamma}{2}(\alpha\bar{x}_m)^2$ term in the MNE profitability in case of R&D decentralization (12d) is introduced to capture the presence of economies of scale in R&D, which according to the literature represent a major centripetal force. If R&D is decentralized these economies of scale are not fully exploited, implying an increase in R&D expenditure for the same amount of resources devoted to R&D.

4. Main results

4.1 Location factors influencing where to establish a foreign R&D lab

In this section we will characterise what drives the profitability of the MNE in case of R&D decentralization. Identifying the subsidiary specific profitability drivers in case of decentralization, will allow us to highlight which are the main location factors influencing the decision of the MNE to undertake R&D activities in a specific foreign market. We focus the discussion on local market size or cost conditions and the local know-how base as location factors.

By solving for optimal output in the case of decentralization, respectively for the parent in country I and the subsidiary and the local firm in country II, we obtain:

$$\hat{q}_p^d = \frac{M_p}{2b_I} + \frac{(1-\alpha)\bar{x}_m}{2b_I} + \frac{\beta^{Is}\alpha\bar{x}_m}{2b_I} + \frac{\beta^{Is}(\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l}{2b_I} \tag{17}$$

$$\hat{q}_s^d = \frac{M_s}{(4-\varphi^2)b_{II}} + \frac{2\beta^{Ip}(1-\alpha)\bar{x}_m}{(4-\varphi^2)b_{II}} + \frac{(2\beta^{Xl}\alpha\bar{x}_m - \varphi)\bar{x}_l}{(4-\varphi^2)b_{II}} + \frac{(2-\varphi\beta^{Xs}\bar{x}_l)\alpha\bar{x}_m}{(4-\varphi^2)b_{II}} \tag{18}$$

where $M_p = A_I - c_p$ and $M_s = (2-\varphi)A_{II} - 2c_s + \varphi\ c_l$ represent the initial (no innovation) demand-cost margin. When discussing plant level profits, we can focus our attention on these equations since the profitability of each unit (parent, subsidiary) is increasing in its own equilibrium output [3].

The main focus is the impact on *subsidiary profitability*. Expression (18) shows that, as expected, the subsidiary output, and hence profitability, increases with host country market size (captured by M_s and by the demand slope $1/b_{II}$). This represents a first important location factor. The second term represents the extent to which central R&D resources $(1-\alpha)\bar{x}_m$ can still be deployed by the subsidiary, even in case of decentralization, but only imperfectly given imperfect internal transfers $\beta^{Ip} \leq 1$. The better able the subsidiary is in directly using the central R&D resources, the higher the subsidiary profitability. Hence, closer matched locations requiring less adaptation of central know-how are more interesting location sites, ceteris paribus.

Less evident as location factor is the role of local know-how ($\bar{x}_l$) and incoming and outgoing external spillovers to which we now turn. The interesting aspect brought about by expression (18) is the way in which these knowledge transfers interact with product market competition.

From a technology sourcing perspective, the size of the local know-how base ($\bar{x}_l$) serves as an important location factor. The model shows that the local rival's own R&D ($\bar{x}_l$) affects subsidiary profitability in three ways, two of which are captured by the third term in Eq. (18). The first effect is due to the incoming external technological spillovers enjoyed by the subsidiary when undertaking innovative activity in loco ($(\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l$). This effect is positive. But the extent to which $\hat{q}_s^d$ is increasing in $\bar{x}_l$ due to this effect depends on the subsidiary absorption capacity, which depends on the own R&D resources decentralized to the subsidiary.

The second effect of local know-how $\bar{x}_l$ on subsidiary profitability comes via product market competition and is negative. A higher level of local producer R&D resources, $\bar{x}_l$ will make the local competitor stronger in the product market which will have a negative impact on the subsidiary output level. This impact is stronger the more intense the competition is in the product market between the two producers (i.e. the higher is φ).

Thirdly, $\bar{x}_l$ increase the local firm ability to capture the outgoing external spillovers generated by the subsidiary. This is captured by the last term in Eq. (18). Via this route, the local know-how base has a negative impact on $\hat{q}_s^d$ and hence on affiliate profitability. A local firm with a stronger R&D base will be better able to absorb know-how from the subsidiary thus becoming a stronger competitor. This effect depends on product market competition (as shown by the fact that the outgoing external spillover $\beta^{Xs}\bar{x}_l\alpha\bar{x}_m$ is multiplied by φ). For instance, if $\varphi = 0$, β^{Xs} has no effect on $\hat{q}_s^d$ since in this case the subsidiary is not affected negatively if its know-how is disseminated to the local economy.

The necessary and sufficient condition for $\hat{q}_s^d$ to be increasing in the local firm's R&D ($\bar{x}_l$) is thus :

$$(2\beta^{Xl} - \varphi\beta^{Xs})\alpha\bar{x}_m > \varphi. \tag{19}$$

which shows that the probability that the condition holds, increases with product differentiation (lower φ), and with the difference in intensity between incoming and outgoing external spillovers. Hence we compare the net effect via external spillovers with the competition effect. Eq.(19) is the condition that needs to hold for the R&D investment by the local firm ($\bar{x}_l$) to lead to an increase in the subsidiary profitability.

The size of the local know-how base $\bar{x}_l$ affects also the *profitability of the parent company*. Expression (17) allow us to discuss the impact of $\bar{x}_l$ on the parent plant when decentralizing R&D to the subsidiary. The last term in Eq. (17) shows that, in the case of decentralization, the parent plant profits from the incoming external spillovers when allocating R&D resources in country II. In fact $\hat{q}_p^d$ (and thus parent's profitability) is increasing in $\bar{x}_l$ (the amount of R&D undertaken by the local producer) at least to the extent

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[3] We have that: $\hat{\Pi}_m^d = b_I(\hat{q}_p^d)^2 + b_{II}(\hat{q}_s^d)^2 - \frac{\gamma}{2}(\alpha\bar{x}_m)^2$ and $\hat{\pi}_l^d = b_{II}(\hat{q}_l^d)^2$

that β^{Xl} (external spillovers of know-how from the local producer to the subsidiary) exists. Furthermore, since the absorption capacity of each unit is firm-specific, the amount of potential spillovers appropriated by the subsidiary and then passed to the parent is increasing in the subsidiary's own R&D ($\alpha\bar{x}_m$). Hence the more R&D is decentralized to the subsidiary the larger the positive effect from sourcing local spillovers on the parent plant profits. However the benefits for the parent from the learning which is associated to locating R&D activities abroad depends also on the MNE's ability to transfer this knowledge internally from the subsidiary to other units of the MNE (i.e. on β^{Is}). Thus the internal and external transfer mechanisms interact in determining the final effect for the parent.

The last term in Eq. (18) accounts for the "own R&D effect", which is certainly positive since $\beta^{Xs}\bar{x}_l \leq 1$. This term shows that the subsidiary output and hence profitability is increasing in the amount of R&D undertaken in country II ($\alpha\bar{x}_m$), even when allowing for the fact that part of this knowledge may leak to the local firm. As discussed supra, the size of the outgoing external spillover is influenced by the absorption capacity of the local firm, i.e. $\beta^{Xs}\bar{x}_l$, and the intensity of product market competition.

The positive effect of own R&D on $\hat{q}_s^d$ is reinforced by the fact that the subsidiary absorption capacity, and thus the amount of learning from the local producer, i.e. the external incoming spillover, depends on $\alpha\bar{x}_m$, as shown in the third term in Eq. (18). Hence own R&D resources in the subsidiary plant also serve to enhance the learning effect from the local economy.

The necessary and sufficient condition for $\hat{q}_p^d$ to be increasing in the subsidiary's own R&D ($\alpha\bar{x}_m$) is

$$\beta^{Is}(\beta^{Xl}\bar{x}_l + 1) > 1 \qquad (20)$$

4.2 The MNE decision to decentralize its R&D activities

4.2.1. Conditions for R&D decentralization

The solution of the first stage game allows to identify under which condition the MNE will decide to decentralize its R&D activities, i.e. locate a share of its R&D activities in country II assigning a role in its overall research effort to the subsidiary operating there.

The MNE will choose decentralization iff :

$$\hat{\Pi}_m^d - \hat{\Pi}_m^c > 0 \tag{21}$$

Hence discussing the decentralization decision involves comparing both subsidiary and parent profitability in case of decentralization versus centralization.

Let us recall that:

$$\begin{aligned}\hat{\Pi}_m^d - \hat{\Pi}_m^c &= (\hat{\pi}_p^d - \hat{\pi}_p^c) + (\hat{\pi}_s^d - \hat{\pi}_s^c) - \frac{\gamma}{2}(\alpha \bar{x}_m)^2 \\ &= b_I[(\hat{q}_p^d)^2 - (\hat{q}_p^c)^2] + b_{II}[(\hat{q}_s^d)^2 - (\hat{q}_s^c)^2] - \frac{\gamma}{2}(\alpha \bar{x}_m)^2 \\ &= b_I[(\hat{q}_p^d + \hat{q}_p^c)(\hat{q}_p^d - \hat{q}_p^c)] + b_{II}[(\hat{q}_s^d + \hat{q}_s^c)(\hat{q}_s^d - \hat{q}_s^c)] - \frac{\gamma}{2}(\alpha \bar{x}_m)^2\end{aligned} \tag{22}$$

We consider first the effect of R&D decentralization on parent's and subsidiary's variable profits separately, before analyzing the overall effect. This way of proceeding will allow us to highlight how R&D decentralization affects the profitability of the different units of the MNE. [4]

From Eq. (22), since output levels are nonnegative, $\hat{q}_j^k \geq 0$ (with *k=c,d* and *j=p,s,l*), we have that:

$$Sign\ (\hat{\pi}_p^d - \hat{\pi}_p^c) = Sign\ (\hat{q}_p^d - \hat{q}_p^c) \tag{23}$$

$$Sign\ (\hat{\pi}_s^d - \hat{\pi}_s^c) = Sign\ (\hat{q}_s^d - \hat{q}_s^c) \tag{24}$$

Thus the necessary and sufficient conditions for $(\hat{q}_p^d - \hat{q}_p^c) > 0$ and $(\hat{q}_s^d - \hat{q}_s^c) > 0$ represent sufficient conditions for the MNE variable profits to increase when R&D is decentralized.

4.2.2. The impact of R&D decentralization on the parent's plant profits

We first discuss the *effect of R&D decentralization on the parent plant's profitability*. As to the effect of R&D decentralization on the parent equilibrium output level (and thus on parent's profitability), we have that:

$$\hat{q}_p^d - \hat{q}_p^c = -\frac{(1-\beta^{Is})\alpha \bar{x}_m}{2b_I} + \frac{\beta^{Is}\beta^{Xl}\alpha \bar{x}_m \bar{x}_l}{2b_I} \tag{25}$$

The first term captures the negative impact that R&D decentralization has on the parent equilibrium output level. This effect arises from the short run nature of the problem examined. Being in the short run, the total amount of resources devoted to R&D by the MNE

[4] Disentangling parent and affiliate profits from the decentralization choice is interesting when considering the bargaining process internally within the MNE. For instance if the decision to decentralize R&D will only be taken if at least each party benefits, this implies that $(\hat{\pi}_p^d - \hat{\pi}_p^c)$ >0 and $(\hat{\pi}_s^d - \hat{\pi}_s^c)$ >0 need to hold in addition to (21).

is given and consequently the choice of allocating R&D abroad implies lower R&D resources at home. This has a negative repercussion on the parent equilibrium output and hence profitability. This effect is at least partly compensated by the fact that the subsidiary transfers the know-how it creates back to the parent. This transfer is however imperfect with $\beta^{Is} \leq 1$. The negative effect is thus mitigated by internal transfers β^{Is}, and hence depends on the ability of the subsidiary to transfer know-how to the central level. Only in the extreme case of perfect internal transfers $\beta^{Is} = 1$ this negative term disappears.

The second term of (25) captures the beneficial effect of R&D decentralization on the parent's output level from being able to gain access to the foreign pool of potential spillovers generated by local producers, cf supra. The benefit for the parent however again depends on the value of β^{Is}. Thus the ability of the subsidiary to transfer back knowledge to the parent acts as a filter. Whether the parent benefits from the incoming external spillovers also depends on the absorption capacity of the subsidiary. Since the subsidiary absorption capacity depends on its own R&D (given by $\alpha\bar{x}_m$), both the positive and the negative effects of R&D decentralization on parent's profitability are rising in the amount of R&D resources allocated to the subsidiary.

The necessary and sufficient condition for $\hat{q}_p^d - \hat{q}_p^c > 0$ and hence for parent profits to be larger in case of decentralization, i.e. $\hat{\pi}_p^d - \hat{\pi}_p^c > 0$, is condition (20): $\beta^{Is}(\beta^{Xl}\bar{x}_l + 1) > 1$. This condition clearly indicates that the ability of the subsidiary to channel back know-how is a crucial determinant of the effect of R&D decentralization on parent's profitability. It stresses the crucial role of internal knowledge management within the MNE. The condition also brings to attention the importance of the interaction between internal and external knowledge transfer mechanisms. The larger the incoming external spillovers, the more likely that (20) will hold. Although the sign of $(\hat{q}_p^d - \hat{q}_p^c)$, does not depend on the amount of R&D resources decentralized, the magnitude of the positive (negative) effect is increasing in $\alpha\bar{x}_m$ and the size of country I.

4.2.3. The impact of R&D decentralization on the subsidiary's profits

The effect of R&D decentralization on the subsidiary output (and thus *the impact on subsidiary profitability*) depends upon:

$$\hat{q}_s^d - \hat{q}_s^c = \frac{2(1-\beta^{Ip})\alpha\bar{x}_m}{(4-\varphi^2)b_{II}} + \frac{2(\beta^{Xl}\alpha\bar{x}_m)\bar{x}_l}{(4-\varphi^2)b_{II}} - \varphi\frac{(\beta^{Xs}\bar{x}_l)\alpha\bar{x}_m}{(4-\varphi^2)b_{II}} \quad (26)$$

The first term in Eq. (26) is connected to the adaptation motive for R&D decentralization, i.e. with the demand related motives for establishing a foreign R&D lab. When the MNE allocates R&D resources to the host country ($\alpha\bar{x}_m$) instead of devoting them to the parent lab, the foreign lab's innovative effort is tailored to satisfy local needs and benefits from proximity with local production. Thus the subsidiary can avoid the adaptation costs that it would have to incur if the MNE had chosen to centralize all R&D in the home country. The lower β^{lp}, the smaller the share of the knowledge generated by the parent which is of use in the host country, and thus the greater the benefits of localizing R&D where there is production. That is why the benefits of undertaking $\alpha\bar{x}_m$ R&D in loco is weighted by the term ($1-\beta^{lp}$) which can be considered as representing the unit cost of adapting to local conditions the know-how transferred by the parent to the subsidiary. If $\beta^{lp}=1$ the first term in Eq. (26) vanishes, showing that in the extreme case of perfect internal knowledge transfer from the parent to the subsidiary (and thus in the absence of adaptation costs) there is no incentive to decentralize R&D due to this motive.

The second term in Eq. (26) reflects the supply related motives for R&D decentralization, connected with the learning motive. It captures the effect of incoming external spillovers which arise because of the proximity between the subsidiary lab and the local producer lab. By decentralizing R&D, the MNE becomes able to absorb from the local firm, benefiting from incoming external spillovers. Eq. (26) shows that the positive effect of incoming external spillovers on the subsidiary profitability is not affected by product market competition, i.e. connected with φ and thus does not work via product market competition.

However there are also dangers associated to localizing R&D resources close to local competitors. These costs are represented by the third term in Eq. (26) capturing the effect of the outgoing external spillovers. Due to lab proximity, at least part of the know-how created by the subsidiary will leak to the local producer. The dissemination of the subsidiary's own R&D to the local firm has a negative impact on the subsidiary profitability since it increases the local firm competitiveness in the product market. Thus the outgoing external spillovers sort their effect via product market competition. That is why the intensity of the negative impact of the outgoing external spillovers depends on φ (the product differentiation parameter). The higher product differentiation and thus the less intense product market competition (the lower φ), the lower the costs of R&D proximity. The extent to which the local producer can benefit from these spillovers depends on its absorptive capacity which in turn is determined by its own R&D resources $\bar{x}_l$. Thus the stronger the know-how base of the local competitor, the larger the negative impact on subsidiary profits of the outgoing external spillovers.

The necessary and sufficient condition for $\hat{q}_s^d - \hat{q}_s^c > 0$ (and hence for subsidiary profits to be higher in case of R&D decentralization, i.e. for $\hat{\pi}_s^d - \hat{\pi}_s^c > 0$) becomes:

$$2(1-\beta^{Ip}) + 2\beta^{Xl}\bar{x}_l > \varphi\beta^{Xs}\bar{x}_l \tag{27}$$

from which we have

$$2 + 2\beta^{Xl}\bar{x}_l > 2\beta^{Ip} + \varphi\beta^{Xs}\bar{x}_l \tag{28}$$

If the external spillover parameter is symmetric ($\beta^{Xl} = \beta^{Xs}$), condition (28) always holds since φ <2 and $\beta^{Ip} \leq 1$. Thus if the intensity of external technological spillovers (i.e. β^X) is sector/technology specific, the subsidiary equilibrium output (and profits) will increase when R&D is decentralized for any value of α, β^{Ip}, and φ. This is the case since the positive effect of the incoming external spillovers is direct, with incoming external spillovers a pure externality, while the negative effect of the outgoing external spillovers is mediated via competition in the product market. On the other hand, if ($\beta^{Xl} = \beta^{Xs}$), condition (20) required for parent's profitability to rise, does not necessarily hold[5]. Thus the model suggests that R&D decentralization is more likely to result in higher profitability for the subsidiary than for the parent unit.

If the external spillover parameter is asymmetric ($\beta^{Xl} \neq \beta^{Xs}$), we obtain from Eq. (28) that the *sufficient* condition for $\hat{q}_s^d - \hat{q}_s^c > 0$ (and for subsidiary profits to be higher in case of R&D decentralization, i.e. for $\hat{\pi}_s^d - \hat{\pi}_s^c > 0$) becomes:

$$\beta^{Xl} \geq \frac{\varphi}{2}\beta^{Xs} \tag{29}$$

Note that condition (29) is not overly restrictive and allows for the outgoing spillover parameter to be larger than the incoming spillover parameter.

Another special case is when the local firms are no direct competitors, for instance when they would be research institutes or firms with related technologies but which are unrelated in the product market. If φ=0, the negative effect of the outgoing external spillovers vanishes. This means we would have in this case the subsidiary to profit from decentralization ($\hat{\pi}_s^d - \hat{\pi}_s^c > 0$) for all values of the other parameters.

Overall, it is likely that the decision to assign an innovative role to the subsidiary will result in an increase of the latter profitability, which explains the subsidiaries' call on part of the R&D resources of the MNE.

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[5] If $\beta^{Xl} = \beta^{Xs}$ this implies that since $\beta^{Xl}\bar{x}_l \leq 1$, condition (20) does not hold for $\beta^{Is} \leq 0.5$.

4.2.4. The impact on the MNE's total profits

To assess the *overall effect on the MNE profitability* however requires that due consideration should be given not only to the impact on the subsidiary profitability but also to the effects on parent profitability and to the role of the additional R&D costs due to foregone economies of scale. In total, we have six effects that form the benefits and the costs from R&D decentralization:

- (B.1) avoidance of adaptation of central innovations by the subsidiary (first term in (26))
- (B.2) benefits from the incoming external spillovers to the subsidiary (second term in (26))
- (B.3) benefits from the incoming external spillovers to the parent (second term in (25))

- (C.1) the foregone economies of scale in R&D (last term in (22))
- (C.2) the impact on the subsidiary from outgoing external spillovers (third term in (26))
- (C.3) the loss of R&D resources for the parent plant which are decentralized to the subsidiary but not fully recoverable due to imperfect internal transfers (first term in (25))

In order to fully solve the first stage game (i.e. the R&D decentralization choice) we need to compare the total MNE's profits corresponding to each of the two potential states (decentralization/centralization) (Eq. (22)). The complexity of the expressions for equilibrium profits makes it difficult to perform analytical comparisons to fully characterize the equilibrium choices in general. Nevertheless, we can discuss the factors driving costs and benefits of decentralization and characterize the outcome for some special cases. Hence, rather than evaluating the conditions required for $\hat{\Pi}_m^d - \hat{\Pi}_m^c > 0$, i.e. for decentralization of R&D to be the solution of the game, we will concentrate mostly on discussing factors that can promote R&D decentralization by analysing the sign of the partial derivative of exogeneous factors on the overall net profits from R&D decentralization.

4.3 Factors affecting the impact of R&D decentralization on total MNE's profits

Of particular interest to consider as factors influencing the R&D decentralization decision by the MNE are the local know-how base and the mechanisms to transfer know-how internally and externally.

4.3.1. Local know-how base

A first important factor affecting $\hat{\Pi}_m^d - \hat{\Pi}_m^c$ and hence the R&D decentralization decision, is the *local know-how base* $\bar{x}_l$. From supra we know that a strong local know-how base increases the benefits from incoming external spillovers both for the subsidiary and the parent (B.2 and B.3). But at the same time it enlarges the cost of outgoing external spillovers (C.2) since the local rival will have a stronger absorptive capacity. Already at the subsidiary level, the net effect of a local know-how base can be positive (i.e. C.2 < B.2). For this Eq. (19) was the necessary and sufficient condition, cf supra. If we consider the overall effect of the local know-how base on the incentives to decentralize, Eq.(19) is not only a necessary and sufficient condition to increase subsidiary profitability, cf supra, it is also a sufficient condition for the local R&D base $\bar{x}_l$ to act as a driver for R&D decentralization (i.e. for $\frac{\partial(\Pi_m^d - \Pi_m^c)}{\partial \bar{x}_l} > 0$), as shown in expression (31):

$$\frac{\partial(\Pi_m^d - \Pi_m^c)}{\partial \bar{x}_l} = \frac{\partial(\pi_p^d - \pi_p^c)}{\partial \bar{x}_l} + \frac{\partial(\pi_s^d - \pi_s^c)}{\partial \bar{x}_l} = \\ = \hat{q}_p^d \beta^{Is} \beta^{Xl} \alpha \bar{x}_m + \frac{2}{4-\varphi^2}\left[\hat{q}_s^d (2\beta^{Xl}\alpha\bar{x}_m - \varphi\beta^{Xs}\alpha\bar{x}_m - \varphi) + \hat{q}_s^c \varphi\right] \tag{31}$$

Eq. (31) is not always positive, which would imply that a local know-how base is not a univocally positive factor for R&D decentralization This would happen when the cost of outgoing external spillovers becomes very important. This cost would start to dominate when competition is strong, i.e. φ large, and the learning is asymmetric, i.e. β^{Xs} is high, while β^{Xl} is low. [6]

4.3.2. Internal transfer of know-how

Another important factor determining the size of both benefits and costs to decentralization is the *process of internal transfer of know-how* within the MNE. We have that

$$\frac{\partial\ (\hat{\Pi}_m^d - \hat{\Pi}_m^c)}{\partial \beta^{Is}} = (\alpha\bar{x}_m + \beta^{Xl}\alpha\bar{x}_m\bar{x}_l)\hat{q}_p^d > 0 \tag{32}$$

Eq. (32) shows that the incentive to decentralize R&D is increasing in β^{Is}. A better internal transfer of know-how from subsidiary to parent results in lower costs of decentralization (lower C.3) and in larger benefits from incoming external spillovers to the

[6] For instance, it can easily be checked that for the extreme case when ($\beta^{Xs}\bar{x}_l$)=1, β^{Xl}=0, and φ>0, (31) will indeed be negative if β^{Ip}<0.5. If β^{Ip} is large, we require for (31) to be negative that q^d_s is large enough. Eg β^{Ip}=1 requires q^d_s>1/3.

parent (higher B.3). For instance, perfect internal transfers from the subsidiary to the parent, $\beta^{Is}=1$, will eliminate the parent plant's adaption cost (C.3).

A better internal transfer from the parent to the subsidiary does not always discourage decentralization[7]. In fact β^{Ip} has an ambigous effect on the incentive to invest abroad in R&D. We have that

$$\frac{\partial \ (\hat{\Pi}_m^d - \hat{\Pi}_m^c)}{\partial \beta^{Ip}} = \frac{4\bar{x}_m}{(4-\varphi^2)}[(1-\alpha)\hat{q}_s^d - \hat{q}_s^c] \qquad (33)$$

from which

$$sign\frac{\partial(\Pi_m^d - \Pi_m^c)}{\partial \beta^{Ip}} = sign\left((1-\alpha)\hat{q}_s^d - \hat{q}_s^c\right) \qquad (34)$$

which implies that, if the subsidiary's output in case of decentralization is large enough, a more efficient internal transfers from the parent may actually act as incentive for R&D decentralization

4.3.3. External transfer of know-how

Since both parent and subsidiary enjoy higher profits in case of decentralization when there are more spillovers from the local source (see (B.3) & (B.2)), we have

$$\frac{\delta \ (\hat{\Pi}_m^d - \hat{\Pi}_m^c)}{\delta \beta^{Xl}} = [\beta^{Is}\alpha\bar{x}_m\bar{x}_l]\hat{q}_p^d + 2[\frac{2\alpha\bar{x}_m\bar{x}_l}{(4-\varphi^2)}]\hat{q}_s^d > 0 \qquad (35)$$

This means that higher spillovers *from* the local source to the MNE univocally acts as an incentivator for R&D decentralization. But of course: since subsidiary profits will decrease with higher spillovers *to* the local source (see C.2), we have at the same time:

$$\frac{\partial \ (\hat{\Pi}_m^d - \hat{\Pi}_m^c)}{\partial \beta^{Xs}} = -\varphi[\frac{2\alpha\bar{x}_m\bar{x}_l}{(4-\varphi^2)}]\hat{q}_s^d < 0 \qquad (36)$$

Expression (36) implies that being able to prevent spillovers *to* the local source univocally improves the case for R&D decentralization. However since the negative role of β^{Xs} depends on φ, Eq.(36) suggests that investing in knowledge protection measures for lowering β^{Xs} (such as employee conduct rules or measures to reduce knowledge-worker exits) is especially important for firms facing close competitors in production.

[7] Perfect internal transfers from the parent, $\beta^{Ip}=1$, eliminate the subsidiary's adaption motive for decentralization (B.1), leaving only the incoming external spillovers as drivers for R&D decentralization.

If the external spillover parameter is symmetric ($\beta^{Xl} = \beta^{Xs}$), the total effect will be positive since already at the subsidiary level B.2. > C.2, cf supra.

4.3.4. Cross effects

Given the importance of both internal and external knowledge transfers, it is interesting to discuss cross effects. It can easily be shown that [8]:

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\beta^{Xl}\partial\beta^{Is}} > 0 \tag{37}$$

Expression (37) implies that there is a complementarity between internal and external know-how transfers: a better internal know-how transfer process within the MNE, increases the efficiency of mechanisms used to acquire external know-how and vice versa. In other words, the role of the spillovers generated by local innovators as a centrifugal factor to induce a MNE to locate R&D in that country rests also on the ability of the MNE's subsidiary to transfer internally knowledge across geographic boundaries and vice versa.

The cross effects with respect to $\bar{x}_l$ similarly allow to discuss which complementary forces the MNE can use to maximize the positive impact from local know-how sourcing on overall MNE profitability. It is quite easy to show that

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\bar{x}_l\partial\beta^{Is}} > 0\,; \tag{38}$$

and when condition (19) holds

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\bar{x}_l\partial\beta^{Xl}} > 0\,; \tag{39}$$

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\bar{x}_l\partial\beta^{Xs}} < 0\,; \tag{40}$$

When the MNE locates R&D abroad, the MNE is much more likely to benefit from the technology sourcing advantage from decentralization when it has an efficient internal know-how transfer process (high β^{Is}); when it has an efficient process to absorb externally available know-how (high β^{Xl}); and when it can prevent know-how from spilling over to competitors all to easily (low β^{Xs}). These results illustrate again the complementarity between an efficient knowledge management system and the technology sourcing motive for R&D decentralization.

A final important factor to consider as complementary force in technology sourcing is the amount of R&D resources allocated to the subsidiary $\alpha\bar{x}_m$, serving as absorption capacity for external know-how acquisition, but at the same time opening up the possibility of appropriation by local competition.

While condition (27) is sufficient for

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\beta^{Xs}\partial\alpha\bar{x}_m} < 0\,; \qquad (41)$$

conditions (20) and (27) are sufficient for

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\beta^{Xl}\partial\alpha\bar{x}_m} > 0\,; \qquad (42)$$

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\beta^{Is}\partial\alpha\bar{x}_m} > 0\,; \qquad (43)$$

This implies that having more R&D resources located at the subsidiary level increases the extent to which the MNE at the corporate level can benefit from local learning as well as internal know-how transfers from the subsidiary when decentralizing R&D. Equivalently, a higher external spillover level from local sources (high β^{Xl}) and a better ability to use subsidiary know-how at corporate level (high β^{Is}) will push the MNE, when deciding on the optimal amount of decentralizing R&D resources, to allocate more resources to the subsidiary level. On the contrary, a high level of outgoing external spillovers, i.e. low level of appropriability, (high β^{Xs}), will lead the MNE to allocate less R&D resources to the subsidiary.

Finally, condition (19) together with (20) and (27) are sufficient for

$$\frac{\partial^2(\Pi_m^d - \Pi_m^c)}{\partial\bar{x}_l\partial\alpha\bar{x}_m} > 0\,; \qquad (44)$$

Since conditions (19), (20) & (27) are more likely to hold with a high β^{Xl} and a low φ and/or low β^{Xs}, this implies that a sufficiently large incoming external spillover level while having weak competition or high enough appropriability of subsidiary know-how are sufficient conditions for the size of the local know-how base to act as a stimulus for allocating more R&D resources to the subsidiary level.

5. Conclusions

This paper provides a theoretical model on the trade-offs which a MNE faces when assigning subsidiaries an active role in innovation and organizing its R&D decentralized. R&D decentralization avoids having to adapt centrally developed innovations to local

[8] The full expression is not reported for sake of space.

markets. In addition R&D subsidiaries can be used to source locally available external know-how. But the MNE has to organize the transfer of local know-how internally so as to be able to benefit from this location specific know-how throughout the organization. At the same time, decentralization of R&D to the subsidiary level opens up the possible spilling over of valuable know-how to competitors located in the foreign markets.

The proposed model focuses on how the interplay of internal and external knowledge flows interacts with the nature of host market competition to influence the choice of MNEs to effectively disperse internationally its R&D. The intensity of competition in the local market emerges as important in determining the size of both benefits and costs to R&D decentralization. It is especially significant in determining the outgoing spillover costs. In the absence of local competitors in production, the subsidiary will always profit from R&D decentralization in our model. But even if there is local competition to worry about, the cost from outgoing external spillovers is outweighted by the benefit from incoming external spillovers at the subsidiary level, at least when external spillovers are symmetric.

In addition, the model indicates that a strong local know-how base is not necessarily a motive for R&D decentralization. While it increases the benefits from incoming external spillovers both for the subsidiary and the parent, at the same time it enlarges the cost of outgoing external spillovers since the local rival will have a stronger absorptive capacity. This cost could start to dominate when competition is strong and the external spillovers are asymmetric, sufficiently in disfavor of the MNE.

We also find that a more efficient internal know-how transfer process within the MNE from the subsidiary to the parent univocally acts to promote R&D decentralization. It will increase the benefits from incoming external spillovers to the parent. But on the other hand, a more efficient transfer of know-how from the parent to the subsidiary makes the motive for avoiding adaptation by the subsidiary less prevailing. Nevertheless it does not always discourage the MNE from investing abroad in R&D. A better internal know-how transfer process within the multinational increases the efficiency of mechanisms used to source external know-how and vice versa. Hence, the results clearly illustrate the complementarity between an efficient internal and external knowledge management system and the technology sourcing motive for R&D decentralization. Another important complementary force increasing the efficiency of technology sourcing is the decentralized know-how base, which serves to absorb local know-how.

While the model allows to discuss the forces driving costs and benefits of R&D decentralization within multinational firms, a full characterization of the decentralization choice of the multinational requires numerical simulations, given the complexity of the setting. Our future research will move towards obtaining predictions from the model which can be tested against data on R&D decentralization. Extending the model, such as to allow for endogeneous R&D resources, or local competitors reciprocally locating R&D abroad, would allow for model results which are closer to most empirical settings.

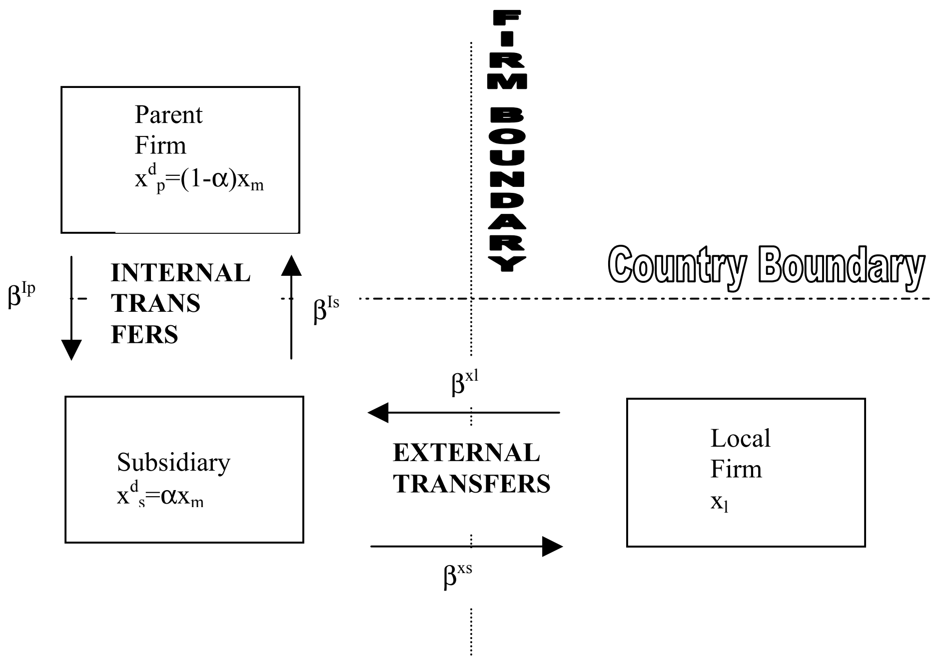

Fig 1A: Internal and External Knowledge spillovers with Decentralized R&D

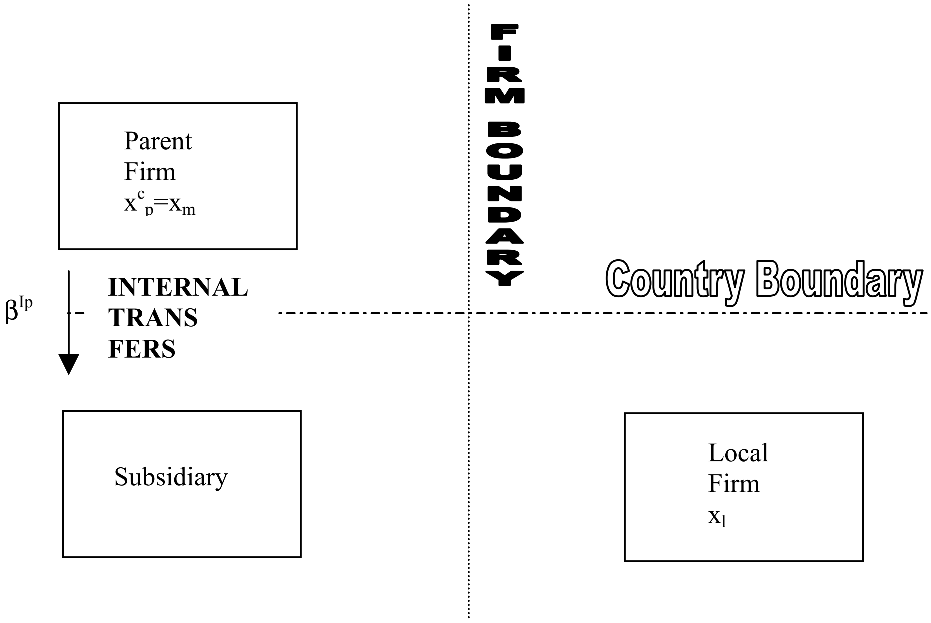

Figure 1B: Knowledge Transfers with Centralized R&D

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