Strategic R&D Location by Multinational Firms: Spillovers, Technology Sourcing, and Competition

RENÉ BELDERBOS
Katholieke Universiteit Leuven and Eindhoven University of Technology

ELISSAVET LYKOGIANNI
Katholieke Universiteit Leuven

REINHILDE VEUGELERS
Katholieke Universiteit Leuven and CEPR

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ABSTRACT
This paper analyzes strategic interaction in R&D internationalization decisions by two multinational firms facing competition of a rival multinational both abroad and in the home market. The model takes into account local inter-firm R&D spillovers, (non-costless) international intra-firm transfer of knowledge, and the fact that internal R&D can increase the effectiveness of incoming spillovers (by increasing the firm’s absorptive capacity). Foreign R&D can be both motivated by product and process adaptation and foreign technology sourcing. One multinational is assumed to be technology leader (in terms of its R&D budget). Results show that greater efficiency of intra-firm transfers and greater spillovers increase the share of R&D located at home by the technology leader. The lagging firm in contrast increases the share of foreign R&D to benefit from increased effectiveness of overseas technology sourcing. Greater product market competition encourages the leading firm to engage in offensive foreign R&D to capture a larger share of the foreign market, while laggards are more likely to concentrate R&D at home to defend their home market position. If a country tightens its intellectual property rights regime to reduce country specific spillovers, it attracts an increased share of R&D by both leader and laggard.

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JEL classification: D21, F23, L16

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1. Introduction

The internationalization of R&D by multinational firms has been a growing phenomenon in the last two decades. The existence of the phenomenon is generally accepted, but its importance, driving forces, and impact not yet clearly understood. An increasing number of empirical studies have examined which firm and host country characteristics affect foreign R&D (e.g. Kuemmerle 1997; Florida 1997; Belderbos, 2001; 2003; Kuemmerle, 1999; von Zedtwitz and Gassman, 2002; Odagiri and Yasuda, 1999; Zejan, 1990; Kumar 1996; Chung and Alcacer, 2002). These studies have suggested that foreign R&D is motivated both by the need to exploit and adapt the investing firms’ technology to local demand and manufacturing conditions, as well as the need to get access to local science and technology resources (technology sourcing). Although the exploitation motive has long been dominant, the evidence suggests that the technology sourcing motive is becoming a major force (Kuemmerle, 1999; Griffith et al, 2003).

In an attempt to better understand the forces driving firms’ R&D decentralisation decisions, recent theoretical studies have examined the incentives to locate R&D abroad. These studies have mainly taken the perspective of a single multinational firm, treating domestic and foreign rival firms as a competitive fringe and thus ignoring strategic interaction among competing MNEs (Norback, 2001; Sanna-Randaccio and Veugelers, 2002). Other contributions have been more concerned with the type of research being allocated overseas (Franck and Owen, 2003), the geography of R&D and manufacturing within countries (Gersbach and Schmutzler, 1999), or with strategic FDI rather than R&D investments (Bjorvatn and Eckel, 2001).

In this paper, we examine the strategic interaction between R&D localization decisions of two multinational firms based in different countries, operating affiliates in each other’s
home markets. The decision to allocate R&D abroad has an impact on the R&D decisions of a the rival multinational, who will determine its best response. The intensity of this strategic interaction in R&D localization between the two multinational firms depends on the degree of product market competition. We examine the different incentives faced by technology leaders and technology laggards in the decision to locate R&D abroad. R&D localization impacts the effective knowledge base of the firms in home and host markets, by influencing the scope for intra-firm international knowledge transfers and inter-firm knowledge spillovers. The model allows both motivations for overseas R&D: to improve foreign affiliate profitability by adapting processes and products to local circumstances and to source knowledge from the local foreign rival. It considers both ‘faces of R&D’: a positive impact on the firm’s knowledge base as well as a positive impact on the effectiveness of knowledge sourcing from external sources (i.e. the firm’s absorptive capacity).\textsuperscript{1} Scale economies in the R&D process (e.g. Kuemmerle, 1999) provide a disincentive to R&D internationalization, while international knowledge transfer neither is costless. In Nash equilibrium, the share or R&D located abroad, depend on international knowledge transfer efficiency, the extent of external spillovers related to intellectual property rights protection (IPR) regimes, and the degree of product market competition.

The remainder of this paper is organized as follows. Section 2 provide a brief overview of the relevant literature to provide background to the formulation of the model of strategic R&D localization. Section 3 describes the basic model and Section 4 analyzes the impact of the main parameters of interest on the optimal allocation of R&D. Section 5 concludes.

\textsuperscript{1} See, e.g. Cohen and Levinthal (1989), Leahy and Neary (1999), and Cassiman et al. (2003).
2. **Background**

The internationalization of R&D by multinational firms has been documented by a number of studies. Dalton et al. (1999) show that US multinationals increased R&D spending abroad from 5.2 billion US dollars in 1987 to 14.1 billion dollars in 1997; the latter figure was 11 percent of total R&D expenditures in the US. For Japanese multinational firms, reported overseas R&D in a survey by Japan’s Ministry of Economics, Trade, and Industry stood at 279 billion Yen in 1997 increasing to 411 billion Yen in 2002, with the ratio of overseas to domestic R&D reaching 4.1 percent. At the firm level, Gassman and von Zedtwitz (2002) find substantially higher foreign R&D ratios for leading multinational firms in 1999.

In an attempt to explain the growing phenomenon of internationalisation of R&D, a number of empirical studies, often based on surveys and case-studies, have investigated into more detail the (changes in) firms’ motivations in carrying out R&D abroad and the specific R&D activities that are performed abroad. This literature (e.g. Kuemmerle 1997, Florida 1997, Reger 2001, Le Bas and Sierra 2002, Odagiri and Yasuda, 2003) suggests that whereas traditionally overseas R&D was conducted to adapt home-developed technologies to foreign markets (‘home base exploiting’ R&D), foreign R&D activities are now becoming more important vehicles to access local technological expertise abroad and to create new technologies that can be used on all the MNE’s markets (‘home base augmenting’ R&D). A number of studies have analysed the R&D expenditures by foreign affiliates of MNEs to look for which countries are most likely to attract foreign R&D expenditures (Zejan,1990; Fors, 1996; Kumar, 2001;Odagiri & Yasuda, 1996; Belderbos, 2001, 2003; Chung and Alcacer, 2002). R&D is found to be attracted to larger local markets and markets with high per capita income, and follow MNEs’ manufacturing and sales activities, reflecting technology exploitation motives. R&D activities are also located in countries with an abundance of
scientists and engineers and a technological lead in industry of the investing firm, reflecting technology sourcing motives. Japanese firms in particular, have been found to use joint ventures and acquisitions relatively frequently to build up effective overseas R&D bases more rapidly, with firms with technologically lagging firms most active in this regard.

The growing importance of ‘technology sourcing’ strategies, where affiliate R&D is used as vehicle to access local technological expertise abroad, is also confirmed by studies analyzing patent citation data. Almeida (1996) analyses the citations contained in a sample of major patents granted by the USPTO to MNEs in the US semiconductor industry and finds that foreign subsidiaries build upon localised sources of knowledge, since the patents cited by foreign affiliates are more likely to have originated in the U.S. or in the same U.S. State where they operate. Frost (2001) also confirmed that geographic proximity matters substantially for technology sourcing and spillovers: foreign firms' subsidiaries were found to cite research by other institutions and firms in the same US state relatively frequently. This is consistent with the finding of Branstetter (2000) that Japanese firms investing in the US have a significantly higher probability of citing other US firms’ patents.

Internationalisation of R&D also has implications for the internal knowledge flows between parents and subsidiaries. Knowledge flows from foreign units to the parent company will be more likely if foreign affiliates are undertaking asset-augmenting type of activities that generate knowledge valuable for the rest of the organization. The challenge for a globally innovating MNE is to effectively transfer locally acquired know-how across its units. Effective intra-firm knowledge diffusion requires ‘dual embeddedness’ on the part of the subsidiary, i.e. embeddedness in both external and in intra-firm networks’ Frost (1998). Empirical studies confirm the traditional flows from headquarters to subsidiaries but find no conclusive support for the transfer of know-how from subsidiaries to headquarters. Frost

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2 These findings relate to a larger body of literature on the degree of localization of spillovers and know-how (e.g. Audretsch and Feldman, 1996). Jaffe et al. (1993) found that being close to an external information source increases the impact of spillovers from that source on internal technological capabilities and know-how.
(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. Recent papers do suggest that overseas R&D geared towards technology sourcing has a positive impact on the productivity of parent operations (Iwasa and Odagiri, 2003; Griffith, Harrison & van Reenen, 2003), suggesting effective reverse technology flows.

A traditional factor favouring centralization of R&D at home rather than dispersing R&D abroad, beyond the classical economies of scale in R&D argument, is the greater risk of dissipation of know how to local competitors, the flip side of potential technology sourcing from local sources. As patent citation data show, foreign subsidiaries do not only acquire local know-how, they are also sources of knowledge spillovers to the local economy. Both Almeida (1996) and Branstetter (2000) provide evidence that patents belonging to foreign firms investing in the US are cited more than local firm patents by US firms. Veugelers & Cassiman (2002) using survey data from a sample of Belgian innovation active manufacturing confirm the evidence for bi-directional knowledge transfers between foreign subsidiaries and local Belgian firms.

In particular when multinational firms are technology leaders and affiliates are located in countries with an insufficiently developed intellectual property rights protection regime, maintaining control over core technologies is a key issue and can discourage foreign R&D. Branstetter et al (2003) provides evidence that R&D by US firms with large patent portfolios is responsive to positive reforms in intellectual property rights protection regimes in host markets. Other studies have found that multinational firms adapt the type of activities located abroad in response to intellectual property rights concerns, with knowledge intensive and higher value added activities reserved for countries with stronger IPR regimes (Lee and Mansfield, 1996; Smarzynska, 2004). Zhao (2004) shows that foreign R&D labs in China
mostly engage in R&D for technologies where the parent can maintain control over key complementary technologies. Hence, overseas R&D does not only provide sourcing opportunities, it may also increase the risk of dissipation of R&D results to foreign rivals, in particular when there are fewer possibilities to protect know how and intellectual property. The negative consequences of unintended outgoing knowledge spillovers will be greatest when the foreign rivals are direct competitors of the multinational in the host country product market, and even more so if the foreign rivals are also competing within the multinational’s main markets.

There has been surprisingly little formal analysis of R&D localization decisions by multinational firms. Norback (2001) develops a model of R&D localization and foreign manufacturing investment by a single multinational firm. He finds that R&D intensive firms are more likely to produce abroad the lower the transfer costs of technology from the headquarters, and found empirical evidence for this in data on Swedish multinationals. Petit and Sanna-Randaccio (2000) study the interaction between R&D investments and reciprocal foreign direct investment by multinational firms based in two countries, but do not allow for R&D localization. The notion that establishing subsidiaries abroad leads to dissipation of know-how is developed in Ethier & Markusen (1996) who find that MNE’s may prefer Exports over FDI to be better able to control knowledge flows. Similarly, Fosfuri (2000) analyses the MNE’s choice between FDI, Exports and Licensing and the vintage of the technology transferred. Siotis (1999) develops symmetric two-firm, two-countries model where an MNE when serving the foreign market through FDI generates spillovers to local competitors, but will also be able to learn from local rivals. If the technology gap between the firms is large, the advanced firm prefers exports over FDI, while the technologically

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3 Fosfuri (2000) assumes that while the licensee may decide to imitate, Exports & FDI can perfectly prevent such imitation. He finds that if imitation is possible, eg because of a lower degree of patent protection in the host country, firms may prefer to choose Exports or FDI which avoids imitation or to license the older technology for which there are less incentives to imitate.
backward firm engages in technology sourcing FDI. Bjorvatn and Eckel (2001) similarly
develop a model of export versus FDI choice for two firms based in different countries. The
extent to which FDI is profitable depends on both the level of technology spillovers among
the firms and the efficiency of technology transfers from affiliates to the headquarters. One
finding is that a technological leader may invest strategically in the market of the follower in
order to pre-empt knowledge sourcing FDI by the follower in the home country of the leader.

A limited number of other papers have been more specifically analysed R&D
decisions in an international context. Cadot and Desruelle (1998) are concerned with different
locational determinants of development and research activities. Firms located in smaller
markets are, on average, less successful in transforming research outputs to products. This
implies a pattern of international specialization in R&D activities according to which firms
located in smaller countries do more research, while firms located in larger countries devote
more resources to the development stage. Franck and Owen (2003) focus on the role of
country-specific stocks of knowledge on R&D localization. In case foreign and domestic
knowledge stocks are substitutes, firms have fewer incentives to locate R&D in the foreign
market, while the opposite holds when knowledge stocks are complementary. Gersbach and
Schmutzler (1999) model a duopoly where firms have to decide on one specific location for
their innovation activities, which may be the same or different from their manufacturing
activities. They allow for both variation in internal transfers (due to transfer costs of
knowledge from the location of innovation to the location of manufacturing) and
geographically bounded external spillovers (from innovation to co-located manufacturing). In
their model, which is more concerned with examining R&D agglomeration within a country
than with international R&D, they find that efficiency of internal transfers promotes
agglomeration of innovation. Sanna-Randaccio and Veugelers (2002) also allow for internal
and external (spillover) knowledge flows while considering the impact of foreign competition.
Their analysis is limited to the internationalization decision of one multinational firm facing only competition from local firms, ignoring interaction effects with potential rival MNEs.

In this paper, we contribute to the literature by examining the strategic interaction between R&D localization decisions of two multinationals based in different countries. The R&D localization decisions depend on the efficiency of international intra-firm transfers, the extent of locally bounded inter-firm spillovers, and the degree of product market competition. We examine the asymmetry in incentives to locate R&D abroad for a technology leader and a technology laggard.

3. A Model of Strategic R&D Localization by Multinational Firms

We develop a simple model of strategic interaction in R&D localization decisions between two multinational firms based in different countries. Each multinational firm operates a subsidiary in the rival firm’s home country and both multinationals are duopolists in the product market of each country, which are segmented markets. Each multinational has to decide what share of its R&D resources to allocate to the foreign subsidiary rather than to the home R&D laboratory at headquarters. This R&D location decision has an impact on the effective knowledge base of the subsidiary and headquarters, and this effective knowledge base affects subsidiary’s and headquarter’s profits, either by reducing costs or by expanding relative demand. The effective knowledge base consists of own R&D resources in the location, international intra-firm transfer of knowledge, and incoming external knowledge spillovers from local R&D of the rival firm. Incoming external knowledge spillovers, however, are only possible if the firm has the capacity to absorb such spillovers, and hence require local R&D.
Profit Functions

Let \( \lambda_i \) denote the share of firm’s \( i \) R&D resources allocated to that firm’s subsidiary with \( \lambda_i \in [0,1] \) and \( i, j = 1, 2, i \neq j \). \( X_i \) and \( X_j \) correspond to the level of firm’s \( 1 \) and firm’s \( 2 \) total R&D resources respectively. Firm chooses the value of \( \lambda_i \) that maximizes total profits (of subsidiary and headquarters), with the profit function given by:

\[
\Pi_i = \Pi_i^P(K_i^P, K_j^S) + \Pi_j^S(K_i^S, K_j^P) - \frac{\delta}{2}(\lambda_i X_i)^2
\]

(1)

where \( K_i^P, K_j^S \) are the effective knowledge bases of firm \( i \) located at the parent (headquarters) and overseas subsidiary; respectively, \( K_j^P, K_j^S \) the knowledge bases of rival firm \( j \). Profits in a country depend directly on the effective knowledge base the firm has in the country, as well as the knowledge bases of the rival firm. The knowledge bases are in turn a function of the R&D resources \( (X_i, X_j) \) and the localization ratios \( (\lambda_i, \lambda_j) \). Geographical dispersion of R&D is costly, since R&D is characterized by scale economies. This is captured by a quadratic cost function given by the last term of (1), with \( \delta \in (0,1) \) indicating the degree of scale economies. The total marginal impact on profits of a change in the localization ratio \( \lambda_i \) is:

\[
\frac{\partial \Pi_i}{\partial \lambda_i} = \frac{\partial \Pi_i}{\partial K_i^P} \frac{\partial K_i^P}{\partial \lambda_i} + \frac{\partial \Pi_i}{\partial K_i^S} \frac{\partial K_i^S}{\partial \lambda_i} + \frac{\partial \Pi_j}{\partial K_j^P} \frac{\partial K_j^P}{\partial \lambda_i} + \frac{\partial \Pi_j}{\partial K_j^S} \frac{\partial K_j^S}{\partial \lambda_i} - \delta \lambda_i X_i \]

(2)
The change in localization affects the knowledge bases of the parent and the subsidiary, but also affects the knowledge bases of parent and subsidiary of the rival firm. The impact of total profits depends on the marginal impact of own and rival firm’s knowledge bases on profits and the degree of scale economies.

**Knowledge bases and profits**

We first discuss how own and rival knowledge bases affect profits. Since we are interested in the role of internal knowledge flows and external knowledge spillovers on knowledge bases and R&D localization decisions, and in order to keep the number of parameters in the model manageable, we assume a simple fixed structure of the marginal impact of knowledge bases on profits:

\[
\frac{\partial \Pi_i}{\partial K_i^p} = \frac{\partial \Pi_i}{\partial K_i^s} = b \quad (3a)
\]

\[
\frac{\partial \Pi_j}{\partial K_j^p} = \frac{\partial \Pi_j}{\partial K_j^s} = -\mu b \quad (3b)
\]

The parameter \( b \) is a scale parameter and captures the positive impact of an increase in the knowledge base, at headquarters or at the subsidiary, on total profits. The knowledge base influences profits positively either by reducing costs and/or enhancing demand, and the parameter \( b \) will depend on the size of the market and the technological opportunities in the industry. For simplicity, we assume this parameter to be equal across firms and markets.

The knowledge base of the rival multinational reduces the relative cost or demand advantage of the firm and has a negative impact on the firm’s profits. The degree to which the rival firm’s knowledge base impacts the firm’s profits depends on the intensity of product
market competition between the two firms. Parameter $\mu$ captures this intensity of product market competition, where we make the conventional assumption that the marginal impact of rival’s knowledge bases on profits is smaller than the marginal impact of the own knowledge bases ($0<\mu<1$). By letting the value of the parameter $\mu$ vary, we can analyse how results are affected by the intensity of rivalry between the MNEs due to different degrees of market segmentation and product differentiation.

Before we can discuss the impact of the firm’s localisation decision, we need to discuss the composition of the firm’s effective knowledge bases, both at the parent and the subsidiary. The effective knowledge base consists of three parts: own R&D resources, internal knowledge transfers, and external knowledge sourcing. We allow the firms to differ in the size of their total own R&D resources. Firm 1 is assumed to have larger R&D resources and is ‘technology leader’, while firm 2 is the technology ‘laggard’, i.e.: $X_1 > X_2$. Let the relative technology lead of the leader, denoted by the parameter $s$, be represented by the ‘laggard to leader R&D ratio’: $s = \frac{X_2}{X_1}$ (with $0<s<1$). The higher $s$ is, the smaller the technology gap between leader and follower.

Firms can transfer knowledge internally from parent to subsidiary and vice versa. These internal knowledge transfers cross national boundaries and are hence international in scope. These transfers *spillovers* are imperfect, not only because of the costs associated with transferring knowledge internationally within the firm, but also because of the need to adapt the transferred know-how to local conditions. Adaptation 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 greater the similarity between the two markets, the smaller will be the need for adaptation. For analytical convenience, we assume symmetry between the two firms and countries in terms of internal transfer efficiency. The internal transfer efficiency is
indicated by the parameter $\beta \ (0 < \beta < 1)$, representing the share of the knowledge base that ‘survives’ if transferred abroad.

*External knowledge spillovers* between the two firms are geographically bounded, and assumed to take occur only between headquarters and subsidiaries located in the same country. Knowledge dissemination requires geographic proximity, in line with the agglomeration literature (e.g. Gersbach & Schmutzler, 1999). External spillovers are determined by technology specific factors (such as the complexity of know how affecting the degree of appropriation, the effectiveness of the legal appropriation regime for specific technologies), or by country specific factors (the strength of IPR protection). Spillovers are bi-directional: a firm benefits from incoming spillovers if it co-locates more R&D, but this will also increase outgoing spillovers to the rival firm. We assume initially that there is symmetry between the two firms and countries in terms of external spillovers, but we will relax this assumption in an extension of the model in Section 4. Parameter $\alpha$ represents the share of knowledge that spills over from the parent (subsidiary) of firm $i$ to the subsidiary (parent) of firm $j$, or the share of knowledge originating from the subsidiary (parent) of firm $i$ that spills over to the parent (subsidiary) of firm $j$, with $0 < \alpha < 1$. The knowledge flows and parameters of the model are depicted in Figure 1.

**INSERT FIGURE 1**

Incoming external spillovers require, and are enhanced, by internal R&D, which provide firms with the ‘absorptive capacity’ to effective source and uses external knowledge. For instance, in case of a foreign subsidiary $i$, the impact of incoming spillovers on the subsidiary’s knowledge base depends on the subsidiary’s absorptive capacity represented by its R&D expenditures, such that $\alpha(1 - \lambda_j)X_j \ast \lambda_i X_i$ is the addition to the knowledge base of
subsidiary due to incoming spillovers. If firms differ in their R&D expenditures, the extent to which external spillovers can be effectively sourced \((\alpha(1 - \lambda_i)X_j \text{ or } \alpha\lambda_j, X_j)\) is firm-specific even though the parameter \(\alpha\) is identical across firms. Firms can influence the effectiveness of external knowledge sourcing through their R&D localization decision.

Given the above assumptions, the effective knowledge base at headquarters of firm \(i\) is given by:

\[
K_i^e = (1 - \lambda_i)X_i + \beta \left[ \lambda_i, X_i + \alpha(1 - \lambda_i)X_j, \lambda_j, X_j \right] + \alpha\lambda_j, X_j, (1 - \lambda_i)X_i
\]  

\(\text{(4)}\)

The effective knowledge base consists of three parts. The first term is internal R&D allocated to the parent (and not to the foreign subsidiary). The second term is the internal knowledge flowing back from the subsidiary of firm \(i\) to the parent. It is the combination of the internal knowledge transfer efficiency parameter \(\beta\) and the potential knowledge base to transfer, with the latter consisting of subsidiary R&D and incoming external spillovers in the foreign country (the benefits to the parent from foreign knowledge sourcing). The third term represents incoming external knowledge spillovers in the home country of firm \(i\), originating from the local subsidiary of rival firm \(j\).

The effective knowledge base of the subsidiary is similarly defined as:

\[
K_i^e = \lambda_i, X_i + \beta \left[ (1 - \lambda_i)X_i + \alpha\lambda_j, X_j, (1 - \lambda_j)X_j \right] + \alpha(1 - \lambda_i)X_j, \lambda_j, X_j
\]  

\(\text{(5)}\)
The first term represents the internal R&D resources in the subsidiary, the second term represents internal knowledge transfers from the parent firm to the subsidiary, and the third term is local knowledge sourcing from the rival parent plant.\footnote{To keep the model tractable, we assume that only internal R&D expenditures are a source of potential outgoing local spillovers, and not the knowledge available in the subsidiary due to internal transfers from the parent. This implies that the MNE can influence inter-firm spillovers through its decentralization decision, with centralization of R&D in the home country most likely to reduce outgoing spillovers.}

The R&D localisation ratio ($\lambda_i$) will affect the effective knowledge base of both the parent and the subsidiary through all three components. It will influence not internal R&D at each plant, internal knowledge transfers and, through the absorptive capacity effect, also the incoming external spillovers. The rival’s localisation ratio ($\lambda_j$), will affect the firm’s effective knowledge base through by influencing the level of potential incoming spillovers both at home and abroad.

\section{Optimal levels of R&D Localization}

\textit{Reaction functions in $\lambda$ and optimal values for $\lambda$}

Using (1)-(5) we can solve for the optimal value for $\lambda$. The reaction function of firm 1 with respect to its rival’s R&D localization ratio becomes:

$$\lambda_1(\lambda_2) = b \alpha s \left(1 - \mu \right) \left(1 + \beta \right) \left[1 - 2 \lambda_2 \right] / \delta$$

(6.1)

For firm 2, the equivalent expression is given by:

$$\lambda_2(\lambda_1) = b \alpha \left(1 - \mu \right) \left(1 + \beta \right) \left[1 - 2 \lambda_1 \right] / \delta s$$

(6.2)
The functions are downward sloping: \(^5\) R&D localization of firms \(i\) and \(j\) are strategic substitutes. If firm \(i\) increases the share of R&D expenditures allocated to its subsidiary, then firm \(j\), ceteris paribus, has an incentive to decrease its own share of R&D expenditures. This reflects the agglomeration enhancing impact of inter-firm knowledge spillovers: firm \(i\) can increase the impact of R&D resources on its knowledge bases by responding to an increase in foreign R&D by rival firm \(j\) (in the home country of firm \(i\)) with increased concentration of R&D resources in its home country. Responding by increase R&D at home increases the firm’s absorptive capacity and allows it to benefit more from the increased sourcing opportunities due to the rival’s increase in local R&D. The intensity of the interaction between the R&D localization strategies of the two firms increases in the level of spillovers, and intra-firm knowledge transfer efficiency, but is decreasing in the R&D decentralization cost, the intensity of product market competition and the technology gap.

The reaction functions are drawn in Figure 2 for a set of reasonable parameter values to which we refer as the ‘benchmark case’: relatively efficient internal transfers (\(\beta=0.8\)), a moderate level of inter-firm knowledge spillovers (\(\alpha=0.3\)), an intermediate level of product market competition (\(\mu=0.6\)), no strong cost disadvantage of decentralising R&D (\(\delta=0.1\)), clear technological leadership of firm 1 (\(s=0.4\)), and the market scale parameter set at \(b=0.8\).

\(\text{INSERT FIGURE 2}\)

Solving for the optimal \(\lambda\) gives the following expression for firm 1, the technology leader and for firm 2, the technology laggard:

\[b\alpha s(1 - \mu)(1 + \beta)\]

\(^5\) This is obvious, as \(b\alpha s(1 - \mu)(1 + \beta)\) is positive.
\[ \lambda_1^* = \frac{b\alpha(\beta + 1)(1 - \mu)\left[2b\alpha(1 + \beta)(1 - \mu) - s\delta\right]}{(4b^2\alpha^2(1 + \beta)^3(\mu - 1)^2 - \delta^2)} \quad (7.1) \]

\[ \lambda_2^* = \frac{b\alpha(\beta + 1)(1 - \mu)\left[2b\alpha(1 + \beta)(1 - \mu) - \frac{\delta}{s}\right]}{(4b^2\alpha^2(1 + \beta)^3(\mu - 1)^2 - \delta^2)} \quad (7.2) \]

From the above it is clear that \( \lambda_1^* > \lambda_2^* \) as long as the existence of equilibrium restrictions for \( \delta \) hold.\(^6\) The leader allocates more R&D abroad than the laggard. The intuition is that the larger R&D budget of the leader allows it to spread R&D over the two locations and to increase profitability of overseas operations without affecting home profits strongly.

**Result:** *The technology leader allocates more R&D abroad than the technology laggard.*

The optimal localization ratio is a complex function of the model parameters. We examine the impact of the parameters of interest (internal transfer efficiency, the extent of external spillovers, and product market competition) on the optimal value of R&D localization, distinguishing between the technology leader and the technology laggard. We will examine the comparative statics as well as numerical analysis to illustrate results.

**Inter-firm Spillovers: \( \alpha \)**

We first examine the impact of the external spillovers parameter \( \alpha \) on the share of foreign R&D, i.e. the sensitivity of localization decisions with respect to the strength of the effectiveness intellectual property rights. For the technology leader, an increase in external spillovers leads to a reduction in the share of R&D resources allocated abroad if the firms’

\(^6\) The conditions for existence of equilibrium are given in the Appendix.
technology lead is greater than a certain threshold level: \(\frac{\partial \lambda_1^*}{\partial \alpha} < 0\) if \(s < s_1\). Technology leaders with a large technology advantage (small \(s\)) are less likely to allocate a substantial share of R&D resources abroad when appropriation is more difficult, since this will allow the laggard firm to benefit more from knowledge spillovers. Numerical simulations suggest that the condition in some case requires a strong technology gap (\(s\) ranges between 0.33 and 0.76). Conversely, the lagging firm’s optimal R&D localization ratio increases in the spillover intensity if the technology gap with the leader is greater than a certain threshold level:

\[
\frac{\partial \lambda_2^*}{\partial \alpha} > 0 \text{ if } s < s_2 \text{ with } s_2 = 1/s_1.
\]

The lagging firm has an incentive to locate more R&D resources near the main R&D base of the leader, which is the leader’s home market, in order to increase its effective know-how base through external sourcing. In addition, having more R&D resources abroad improves its absorptive capacity and further enhances the scope for external sourcing. Compared to these advantages from R&D decentralisation, the disadvantage of outgoing external spillovers to the technology leader is less important for the follower. It is clear if \(s_2\) always holds if the technology gap is not greater than \(s_1\). Numerical simulations suggest that in the base case and in most alternative parameter settings, the threshold value for the follower exceeds 1, such that the condition \(s < s_2\) is not binding.

**Result:** Strong technology leaders allocate less R&D resources abroad if there are stronger inter-firm knowledge spillovers. Technology laggards allocate more R&D resources abroad.

In figure 3 we have drawn the reaction functions for the base case of parameter settings from figure 2. Figure 3 then shows the shift in reaction functions as the spillover parameter

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The precise expression of these and other threshold levels are provided in Appendix.
increases from 0.3 to 0.5. This leads to an outward shift of both reaction functions, resulting in a new equilibrium with lower foreign localisation for the leader and higher localization for the follower.

**Efficiency of intra-firm knowledge transfer: β**

An increase in the intra-firm knowledge transfer parameter reflects more efficient transfer of knowledge within the firm, e.g. because of better knowledge management practices or advances in information and communication technologies. It can also reflect a reduction in market differences between the two countries, reducing the need to adapt knowledge transferred across countries. A high level of β facilitates the transfer of home-laboratory knowledge abroad and hence favour centralization of R&D at home. But at the same time, it increases the incentives for technology sourcing abroad, as knowledge sourced by the subsidiary can be transferred back to benefit parent firm operations more easily.

It can be shown that under strong technology leadership conditions, the first effect dominates and hence more efficient internal technology transfers lead to centralization of R&D at home by the leader: \( \frac{\partial \lambda^*_1}{\partial \beta} < 0 \) if \( s < s_1 \). Conversely, under the same circumstances: \( \frac{\partial \lambda^*_2}{\partial \beta} > 0 \) if \( s < s_2 \); the laggard allocates more R&D resources abroad to benefit from more effective transfer of foreign sourced knowledge, an effect which is more important for the laggard than for the leader.8

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8 The role of the size of the technology gap can also be shown by the cross derivative of localization with respect to the internal transfer parameter and the technology gap parameter \( s \). It can be shown that increasing the gap (a
Result: Strong technology leaders allocate less R&D abroad if internal knowledge transfers are more efficient. Technology laggards allocate more R&D resources abroad.

In figure 4 we have drawn the reaction functions for the base case of parameter settings. It is shown how reaction functions shift as the transfer parameter increases from 0.8 to 0.95. This leads to an outward shift of both reaction functions resulting in a new equilibrium with lower localisation for the leader and higher localisation for the follower.

Insert Figure 4

Intensity of Product Market Competition: $\mu$

The product market competition parameter $\mu$ is an indicator of the effect of the rival firm’s knowledge base on the firm’s profitability. Higher values of $\mu$ indicate a greater intensity of strategic interaction between the two firms. It can be shown that the derivative of R&D localization of the leader with respect to the competition parameter is positive as long as the technology gap between leader and laggard is sufficiently large: $\frac{\partial \lambda^*}{\partial \mu} > 0$ if $s < s_l$.

Increased product market competition makes the leader more aggressive in the rival’s home market and leads to an offensive R&D decentralization to capture a larger share of profits in the foreign market, which is possible because of the weakness of the local rival in its home market. This effect is stronger than the detrimental impact of increased outgoing external spillovers in the foreign market with stronger product market competition. For the laggard, smaller $s$) increases the negative impact of $\beta$ on the localization of the leader, and decreases the positive impact of $\beta$ on the localization of the follower: $\frac{\partial^2 \lambda^*_1}{\partial \beta s} > 0$ and $\frac{\partial^2 \lambda^*_2}{\partial \beta s} < 0$.
increased product market competition leads to a response to defend its home market position by keeping more R&D resources at home: $\frac{\partial \lambda_2^*}{\partial \mu} < 0$ if $s < s_2$.

Result: *Strong technology leaders allocate more R&D abroad in case of stronger product market competition is. Technology laggards allocate less R&D abroad.*

Figure 5 demonstrates the impact of an increase in the intensity of competition by examining the shift in reaction functions. It is shown how reaction function shift as the competition parameter increases from 0.6 to 0.75. The leader’s reaction function becomes flatter while the follower’s becomes steeper, resulting in a new equilibrium with increased localization for the leader and decreased localization for the follower.

Intensity of Product Market Competition and inter-firm Spillovers: $\mu$

Another interesting feature that can be studied with the model is the interaction between the intensity of external spillovers and the intensity of competition. One would expect that the incentive of the leader to engage in offensive foreign R&D would be reduced if localization increases the risk of knowledge dissipation, e.g. due to a weakly developed intellectual property rights regime. This result can be shown to hold under the condition of a relatively large technology gap: $\frac{\partial^2 \lambda_1^*}{\partial \omega \partial \mu} < 0$ if $s < s_1^{\alpha\mu}$. Hence, weak IPR protection reduces the impact of competition on decentralizing R&D resources for the leader. For the follower:
\[ \frac{\partial^2 x_2^*}{\partial \alpha \partial \mu} > 0 \quad \text{if} \quad s < s_{2\alpha}^{\alpha} \quad \text{with} \quad s_{2\alpha}^{\alpha} = 1/s_{1\alpha}^{\alpha}. \] The follower will allocate less R&D at home in response to increased competition if external spillovers are large.

**Result:** Strong technology leaders allocate less R&D abroad as a response to higher product market competition when spillovers are strong. Technology laggards allocate more R&D resources abroad.

The cross derivatives can also be interpreted as showing that the positive impact of a looser appropriation regime on the follower’s decision to locate R&D resources abroad is reinforced when product market competition is stronger. And similarly, stronger product market competition reinforces the negative impact of a looser appropriation regime on the leader’s decision to locate R&D resources abroad. Numerical analysis shows that for reasonable parameters settings the threshold \( s_{2\alpha}^{\alpha} \) exceeds one, hence the cross derivative is always positive. Simulations also show that the threshold value \( s_{1\alpha}^{\alpha} \) does not reach levels below 0.6, such that \[ \frac{\partial^2 x_1^*}{\partial \alpha \partial \mu} < 0 \] holds under relatively mild conditions concerning technological leadership.

**Introducing Different IPR Regimes**

A factor favouring centralization of research activities by MNEs is the increased risk of knowledge dissipation when firms decentralize these activities in foreign countries, especially when rival MNEs operate in the host country. Although localization of R&D abroad increases the firm’s ability to source knowledge from foreign competitors, at the time it also
increases the possibility of knowledge dissipation to the local rivals. We can expect that a MNE will be reluctant to localize R&D in a foreign country where the IPR protection is relatively weak, in which case the unwanted knowledge flows to local rivals will deter R&D decentralization. Conversely a host economy, looking to attract inward R&D, may benefit from a tightening of its IPR regime.

In order to take account of the effect of country-specific IPR protection on MNEs’ R&D localization decisions, we relax the assumptions of the model to allow for different external spillover parameters in each country. We can either have \( \alpha_1 < \alpha_2 \), which reflects the case of stronger IPR protection in the home country of the technology leader, or \( \alpha_1 > \alpha_2 \), which reflects the case of stronger IPR protection in the host country of the technology leader.

With a country specific external spillover parameter, the reaction function of firm 1 is:

\[
\lambda_1(\lambda_2) = bs(1 - \mu)[1 + \beta](\alpha_2 - (\alpha_1 + \alpha_2)\lambda_2) / \delta
\]

(6.1’),

while the optimal share of R&D allocated abroad for firm 1 is given by:

\[
\left( \lambda_{1i} \right) = \frac{b(\beta + 1)(1 - \mu)[b(1 + \beta)(1 - \mu)\alpha_1(\alpha_1 + \alpha_2) - s\delta\alpha_2]}{b^2(1 + \beta)^2(\mu - 1)^2(\alpha_1 + \alpha_2)^2 - \delta^2}
\]

(7.1’).

In a first scenario the technology leader is based in a country where the IPR regime is stronger. This could reflect the case of a technology leading MNE originating in a developed country, competing with a technology lagging MNE originating from a developing country, with the developed country typically having stronger IPR regimes than the developing country. For analytical clarity, we prefer the R&D localisation decision to be affected by differences in IPR regimes in the different countries and not by the level of R&D spillovers.
per se. Therefore, we assume that in case of differences in IPR protection (spillovers), the same ‘on average’ IPR protection in both cases: \( \alpha = \frac{\alpha_1 + \alpha_2}{2} \), with \( \alpha_1 < \alpha < \alpha_2 \).

Comparing the optimal value of the share of R&D resources decentralised for each firm with the base case of no differences in \( \alpha \), we find that if \( \alpha_1 < \alpha_2 \), then \( \lambda_1^* < \lambda_2^* \) and \( \lambda_2^* > \lambda_1^* \).\(^9\) In the case of stronger IPR protection in the leader’s home market, the optimal value of the share of the leader’s R&D resources localised abroad \( \lambda_1^* \) is lower. Since R&D decentralisation increases the probability of knowledge dissipation, the leader is more reluctant to locate R&D in the foreign market where IPR protection is weaker. For the follower firm the opposite holds, since the optimal value of the share of follower’s R&D resources localised abroad \( \lambda_2^* \) increases. The tendency of the leader to centralise R&D at home drives the follower’s actions. The follower increases the share of R&D decentralised in order to benefit from increased sourcing opportunities in the leader’s country since more knowledge is concentrated in that country (eventhough this country has the stricter IPR regime).

**Result:** With stronger IPR protection in the technology leader’s country, the technology leader allocates more R&D at home. The technology laggard allocates more R&D abroad.

In Figure 6 we compare the equilibrium outcomes under the two different cases: the initial model where spillovers have the same magnitude in both countries and the model in which spillovers are stronger in country 2. The initial reaction functions (\( \lambda_1(\lambda_2) \) and \( \lambda_2(\lambda_1) \)) are drawn in Figure 6 for the same set of parameter values as in section 3, while the reaction functions corresponding to the different-spillover-parameter case (\( \lambda_1'(\lambda_2) \) and \( \lambda_2'(\lambda_1) \)) are

\(^9\) The proof is given in the appendix.
drawn for the same set of parameter values with $\alpha_1 = 0.25$ and $\alpha_2 = 0.35$ instead of $\alpha = 0.3$. The graph shows that the equilibrium with $\alpha_1 < \alpha_2$ is characterised by lower R&D decentralisation by the leader and higher R&D decentralisation by the follower.

*INSERT FIGURE 6*

A second scenario that can be considered is the case in which stronger IPR protection characterises the home market of the follower. This scenario would be less common, but could for instance reflect a situation where technology leaders in the European pharmaceutical industry localise part of their research towards the US market which is characterised by relatively stronger IPR protection in biotech. Comparing the optimal value of the share of R&D resources decentralised for each firm we find that if $\alpha_1 > \alpha_2$, then $(\lambda_1^*) > \lambda_1^*$ and $(\lambda_2^*) < \lambda_2^*$. If spillovers are larger in the leader’s country, the optimal value of the share of leader’s R&D resources localised abroad $(\lambda_1^*)$ increases and the optimal share of R&D located abroad for the laggard decreases. Hence the leader’s R&D localization decision is strongly sensitive to differences in IPR regimes, due to the need to reduce outgoing knowledge spillovers to the lagging rival. The action of the laggard again is driven by the leader’s decision to decentralise more R&D abroad: the laggard keeps more R&D abroad to defend its home market and to benefit to an extent from the increased R&D activities performed by the leader there.

*Result:* With stronger IPR protection at the laggard’s country, the technology leader allocates more R&D abroad and the laggard allocates more R&D at home.
The reaction functions for the parameter values $\alpha_1 = 0.35$ and $\alpha_2 = 0.25$ are drawn in Figure 7 and compared to the base case of $\alpha = 0.3$. The reactions function of the laggards shifts up and the reaction function of the leader shifts down, leading to a larger share of R&D decentralisation by the leader and a lower share of R&D decentralisation by the follower.

*Insert Figure 7*

We conclude that independently of the technology lead, when country-specific spillover parameters are introduced into the model, we always see an R&D agglomeration effect in the country with the stronger IPR protection.

5. **Conclusions**

This paper analyzes strategic interactions in R&D internationalization by a multinational firm facing competition of a rival multinational both abroad and in its home market. In allocating R&D investments abroad, the firm may benefit from incoming R&D spillovers due to R&D performed in the local market by the rival multinational (technology sourcing). On the other hand, the firm also faces greater risk of dissipation of know-how from its own R&D investments abroad to its rival. Alternatively, the firm can rely primarily on parent firm R&D and transfer knowledge intra-firm to its overseas operations. The model takes into account the ‘two faces’ of R&D: the positive impact on absorptive capacity increasing the benefits of incoming spillovers, as well as the direct positive effect on the firm’s knowledge base. The decision to perform part of R&D abroad in turn affects the trade off between home and host country R&D faced by the rival firm, with localisation decisions of rival MNEs strategic
substitutes. In equilibrium, the shares of R&D performed abroad depend on the importance of spillovers, the strength of product market competition, the efficiency of intra-firm transfers, and whether the firm is a technology leader (defined in terms of the size of R&D investments) or a technology laggard.

Analytical and numerical results show that greater efficiency of intra-firm transfers leads to a greater reliance on home market R&D by technology leaders if the gap with laggards is sufficiently large. This outcome confirms results of earlier work on R&D localization in the context of a single multinational’s R&D localization decision (e.g. Norback, 2001). Laggards in contrast perform more R&D abroad in this case, because their home market operations can benefit more from overseas technology sourcing. Greater R&D spillovers (e.g. due to a weaker effectiveness of intellectual property rights for the industry) have a similar impact, reducing overseas R&D by leaders due to appropriability concerns, but increasing overseas R&D by laggards due to the technology sourcing motive. Greater intensity of product market competition encourages leading firm to engage in offensive foreign R&D to make use of its technology advantage and to capture a larger share of the local market. This effect is smaller if the leader faces more serious risks of dissipation of knowledge in case of high spillover levels. Laggards in contrast, are more likely to concentrate R&D at home to defend their home market position. If country-specific IPR protection regimes are allowed in the model, the results confirm the reluctance of MNEs to localize R&D in countries with weak IPR regimes (e.g. Branstetter et al, 2003). The model suggests that independently of the technology lead, R&D by both leader and laggard tends to agglomerate in the country with the stronger IPR protection.

To bring the model results closer to most empirical settings, it needs to be extended to deal with more realistic and complex settings. More particularly, further work should examine the role of market asymmetry on R&D localization decisions in combination with
firm asymmetry. Another avenue for future analysis on R&D internationalisation is to test the prediction of the model on data on R&D localization strategies in settings where multinationals from different countries invest in each other’s home markets. Although the model in its current format is very simple, it nevertheless generates clear predictions that can be tested in future empirical analysis.

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APPENDIX

Existence of Equilibrium:

If we assume that the intercept of $\lambda_1(\lambda_2)$ is greater than the intercept of $\lambda_2(\lambda_1)$, we need $\delta < 2b\alpha(1-\mu)(1+\beta)s$ to hold.

In this case, for the existence of equilibrium, $\lambda_1(\lambda_2)$ has to be steeper compared to $\lambda_2(\lambda_1)$, which requires that $\delta < 2\sqrt{\frac{b\alpha(1-\mu)(1+\beta)}{s}}$. In other words, equilibrium requires that the costs of decentralization are not too high.

Threshold Values for Derivatives

The threshold values for the derivatives of the optimal localization ratio with respect to $\alpha$, $\beta$, and $\mu$ are:

$$s_1 = \frac{4c\beta\delta(1+\beta)(1-\mu)}{\delta^2 + 4b^2\alpha^2(1+\beta)^2(\mu-1)^2} = \frac{1}{s_2}$$

For most numerical simulations, $s_2$ exceeds one such that the $s_2$ restrictions are not binding.

The threshold values for the cross derivative of the optimal localization ratio with respect to $\alpha$ and $\mu$ jointly are:

$$s_3 = \frac{8b\alpha\delta(1+\beta)(1-\mu)[4b^2\alpha^2(1+\beta)^2(1-\mu)^2 + \delta^2]}{\delta^4 + 16b^2\alpha^2(1+\beta)^2(\mu-1)^2[2\delta^2 + b^2\alpha^2(1+\beta)^2(\mu-1)^2]} = \frac{1}{s_4}$$

For most numerical simulations, $s_4$ exceeds one, such that the $s_4$ restriction is not binding.
If $\alpha_i < \alpha_z$, then $\bar{\lambda}_i^* < \lambda_i^*$ and $\bar{\lambda}_z^* > \lambda_z^*$, for all parameter values.

Proof:

Solving the model in the case of common spillover parameter and in the case of different spillover parameters in each country, we have:

$$\lambda_i^* = \frac{b\alpha(\beta + 1)(1 - \mu)[2b\alpha(1 + \beta)(1 - \mu) - s\delta]}{(4b^2\alpha^2(1 + \beta)^2(\mu - 1)^2 - \delta^2)}$$

and

$$\left(\lambda_i^*\right) = \frac{b(\beta + 1)(1 - \mu)[b(1 + \beta)(1 - \mu)\alpha_i(\alpha_i + \alpha_z) - s\delta\alpha_z]}{b^2(1 + \beta)^2(\mu - 1)^2(\alpha_i + \alpha_z)^2 - \delta^2}.$$

If we impose $\alpha = \frac{\alpha_i + \alpha_z}{2}$ in the second relationship, then

$$\left(\lambda_i^*\right) = \frac{b(\beta + 1)(1 - \mu)[2b\alpha(1 + \beta)(1 - \mu)\alpha_i - s\delta\alpha_z]}{4b^2\alpha^2(1 + \beta)^2(\mu - 1)^2 - \delta^2}$$

and we can see that if $\alpha_i < \alpha_z$, then $\bar{\lambda}_i^* < \lambda_i^*$.

Similarly, for firm 2, we have:

$$\lambda_2^* = \frac{b\alpha(\beta + 1)(1 - \mu)[2b\alpha(1 + \beta)(1 - \mu) - \frac{\delta}{s}]}{(4b^2\alpha^2(1 + \beta)^2(\mu - 1)^2 - \delta^2)}$$

$$\left(\lambda_2^*\right) = \frac{b(\beta + 1)(1 - \mu)[b(1 + \beta)(1 - \mu)\alpha_2(\alpha_i + \alpha_z) - \frac{s\delta\alpha_1}{s}]}{b^2(\alpha_i + \alpha_z)^2(1 + \beta)^2(\mu - 1)^2 - \delta^2}.$$

If we impose $\alpha = \frac{\alpha_i + \alpha_z}{2}$ in the second relationship, then

$$\left(\lambda_2^*\right) = \frac{b(\beta + 1)(1 - \mu)[2b\alpha(1 + \beta)(1 - \mu)\alpha_2 - \frac{s\delta\alpha_1}{s}]}{4b^2\alpha^2(1 + \beta)^2(\mu - 1)^2 - \delta^2}$$

and we can see that if $\alpha_i < \alpha_z$, then $\bar{\lambda}_2^* > \lambda_2^*$. 


Figure 1: Internal knowledge transfers and external knowledge spillovers

Parent of Firm i

\[ X_i^p = (1 - \lambda_i)X_i \]

\[ \alpha \]

\[ \beta \]

Subsidiary of Firm i

\[ X_i^s = \lambda_i X_i \]

\[ \beta \]

\[ \alpha \]

Parent of Firm j

\[ X_j^p = (1 - \lambda_j)X_j \]

\[ \alpha \]

\[ \beta \]

Subsidiary of Firm j

\[ X_j^s = \lambda_j X_j \]

\[ \beta \]

\[ \alpha \]
Figure 2: Best-response Functions - Base Case

Figure 3: Stronger Inter-firm Spillovers
Figure 4: More Efficient Intra-firm Transfers

Figure 5: Stronger Competition