Multinational ownership and R&D intensity:

The role of external knowledge sources and spillovers

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Abstract

This paper analyzes the drivers of multinational affiliates' R&D intensity, using a unique dataset based on the fourth Community Innovation Survey for Belgium. Specifically, we investigate the role of foreign affiliates' local (host country) embeddedness and of host country spillovers on foreign affiliates' research efforts. Our findings show that foreign affiliates who are able to tap into local knowledge sources demonstrate a higher research intensity, compared to firms lacking such access. Links to clients and public research institutions, in particular, have a powerful impetus on the research effort by foreign subsidiaries. Our findings suggest a complementary relationship between foreign firms' R&D intensity and the internal research efforts of their competitors as a result of demonstration effects, while the use of external R&D by competitors has a negative impact on the research effort of foreign affiliates as a result of technological spillovers. Our findings have important policy implications, especially in terms of the high dependency of the Belgian economy on foreign R&D. One way to attain the R&D intensity put forward by the Lisbon agenda would be to increase public expenditure on research and development, which would also indirectly increase the research intensity of (foreign) firms.

Keywords: R&D intensity, Multinational ownership, Knowledge sources, Spillovers

JEL Classification: F23, L23, O31, O33

1. Introduction

The internationalization of research and development (R&D) is an important component of the ongoing trend towards the globalization of the economy. The internationalization of technology means that inventions, the people generating these inventions, and the ownership of these inventions tend to cross national borders more frequently. An increasing share of technology is owned by firms from a different country than the one of the inventors, thus reflecting the fact that companies have research facilities abroad. The importance of this phenomenon is not really new. Cantwell (1989) already reported an increasing share of patents with the owner and inventor located in different countries. Several reasons explain this phenomenon (Patel and Vega, 1999; Dunning and Wymbs, 1999; van Pottelsberghe de la Potterie and Lichtenberg, 2001). First, some multinational companies (MNCs) set up research facilities abroad in order to adapt their products to local markets and to provide technological support to local subsidiaries: the so-called home-based innovation exploiting strategy. Second, multinationals want to monitor new technology developments occurring in foreign countries and want to tap foreign subsidiaries: the so-called host-based innovation augmenting strategy.

The increasing internationalization of R&D by MNCs is reflected in the growing role played by foreign affiliates in the R&D activities of many countries (UNCTAD, 2005). In 1993, the R&D expenditure of foreign affiliates in host countries worldwide – the operations equivalent of inward FDI in R&D – amounted to about $29 billion (i.e. 10% of global business enterprise spending on R&D). Within a decade, by 2002, that spending had more than doubled to $67 billion or 16% of global business R&D. This growth was more than twice as fast as that of global spending by enterprises on R&D, spending that grew by about 49% over the same period.

The share of foreign affiliates in host-country R&D varies by country. It exceeds 50% in Ireland, Hungary, Belgium, the Czech Republic and Singapore, and 40% in four other countries (Brazil, Sweden, the United Kingdom and Australia in descending order). Conversely, it remained under 10% in the Republic of Korea, Japan, India, Chile and Greece. China is in between with a share of 18% in 1998, rising to about 25% currently. The share of foreign affiliates in the business R&D of developed countries is close to the world average and has been growing gradually, from 11% in 1996 to 16% in 2002. In the developing countries for which data are available, the share of foreign affiliates rose faster than in developed countries (from 2% in 1996 to close to 18% in 2002). In fact, more than two-thirds of the 30 countries for which data were available experienced a rise in the share of foreign affiliates in business R&D after 1995, and this rise was larger in developing countries.

Several studies have specifically illustrated the high dependence of the Belgian economy on multinational firms, both in terms of R&D expenditure, employment and output. For instance, Teirlinck (2005a) showed -on the basis of data from the biannual OECD R&D survey- that over seventy percent of total business R&D in Belgium originated in foreign-owned firms in 2001. More recent OECD figures for 2003 and 2005 put R&D expenditure of foreign affiliates as a percentage of R&D expenditures by all enterprises at around 55 per cent.

In related work, Cincera et al. (2006) use patent data from the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO) between 1978 and 2001 to quantify the ownership structure of patents with Belgian inventors. They find that 70 percent of all patents invented in Belgium are owned by foreign firms, either directly (through foreign assignees) or indirectly (through a Belgian subsidiary of a

foreign MNC). This share has been increasing since the 1970s, when it amounted to about 50 percent.

Therefore, for Belgium, the ability to stimulate foreign R&D is an important challenge in the context of the Lisbon objective to spend three percent of GDP on R&D. In 2000, the heads of state and government of the European Union (EU) set the goal of ``becoming, by 2010, the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" (European Commission, 2002). In 2002, the Barcelona European Council reviewed progress towards the Lisbon goal and agreed that investment in European research and development must be increased with the aim of approaching three percent of GDP by 2010, two thirds of which should be realized through private R&D investments (European Commission, 2002).

While this high dependence on multinational firms has clear advantages in terms of access to international knowledge, there are also some obvious drawbacks related to it. First, foreign affiliates are generally expected to spend relatively less, ceteris paribus, on R&D than their domestic counterparts (Van Beveren, 2008; Un and Cuervo-Cazurra, 2008). A subsidiary of a foreign MNC can access other countries' technological and scientific bases through its access to the parent firm or through its access to other subsidiaries. As such, the subsidiary of a foreign MNC benefits from its access to technology developed by the MNC, thus reducing the need to invest in R&D. This is an important drawback, as it suggests that a euro of funding spent to attract a foreign firm's R&D will yield a lower return on investment (lower R&D effort, ceteris paribus), compared to the same euro spent to fund a domestic firms' innovation efforts.

Second, Veugelers and Cassiman (2004) find that although foreign multinational firms enjoy superior access to international knowledge flows, they are not significantly more likely to transfer this knowledge to the local economy compared to domestic firms. Hence, the benefits (spillovers) resulting from the generation of knowledge are likely to be smaller for foreign firms, compared to local enterprises.

Taking into account the high dependence of the Belgian economy on foreign research spending, especially in light of the Lisbon target, the question arises what determines foreign firms' research efforts in the host country. The main objective of this paper is therefore to analyze and determine the drivers of R&D intensity of foreign firms located in Belgium. Given the highly transnational nature of the Belgian economy, important insights might be obtained from this study that could be useful for other countries as well. Specifically, insights into the determinants of foreign affiliates' research intensity might allow host countries to create an environment conducive to foreign innovation efforts, allowing them to attract more research activities and hence enabling them to reach the Lisbon target.

Apart from its obvious policy relevance, the paper contributes to the literature in a number of important ways. First, this is the first paper to investigate to what extent foreign affiliates' research activities are shaped by its access to and use of local knowledge sources at the firm level. Specifically, we hypothesize that foreign affiliates are able to overcome part of their "liability of foreignness" in terms of innovation by tapping into local knowledge sources. We identify six different types of knowledge sources: *suppliers, competitors, clients, private institutions, universities* and *public research institutes*.

Second, most of the literature on innovation by multinational enterprises has focused on the location of technological activities in particular countries, regions or sectors, the spillovers of MNC subsidiaries onto domestic firms, and the development, coordination, and transfer of technology in the network of MNC subsidiaries (Cantwell, 2001). In a similar, yet contradictory vein, this paper will target knowledge spillovers from domestic firms towards multinational subsidiaries. Hence, rather than investigating whether multinational firms transfer their knowledge to local firms, we investigate to what extent foreign firms are able to benefit from the knowledge generated by other firms (local and multinational) within the same sector of activity.

The rest of this paper is organized as follows. Section 2 discusses the related literature and puts forward hypotheses, while section 3 discusses the data set and relevant summary statistics. Section 4 deals with the empirical analysis and section 5 concludes.

2. Literature

Innovative effort is traditionally expected to take place mainly in the home country of multinational enterprises (Castellani and Zanfei 2006). This view is consistent with the product life cycle hypothesis first introduced by Vernon (1966), and is further explained by economies of scale associated with R&D efforts; the importance of learning activities, which are supported by economies of agglomeration; and the importance of access to a rich and growing market to introduce innovations. This concentration of strategic innovative activities in the home country allows for an intensified specialization and division of labor in innovation and the utilization of scale economies, and avoids additional costs of transmitting knowledge to the local subsidiary.

However, there is growing evidence[1] pointing to a "globalization of innovation" trend, meaning that foreign subsidiaries are increasingly carrying out R&D themselves. The R&D resources of any foreign subsidiary can play one or both of two roles: facilitate local adaptation of the MNC's products and services and/or enable the creation and acquisition of globally relevant technology for the entire corporation (Feinberg and Gupta, 2004).

The first strategy has been labeled as asset exploiting, home base exploiting, competence exploiting or market seeking. Asset exploiting strategies are associated with a view of multinational enterprises as a means to exploit firm-specific advantages in foreign markets (Dunning, 1973, Markusen, 1995, Barba Navaretti and Venables, 2004). Research and development of the subsidiaries support the exploitation by adapting technologies, products and processes to local needs, consumer tastes, regulation, etc. (Dachs and Ebesberger, 2009).

Some evidence on the organization of innovative activities within multinational enterprises points towards exploitation strategies. Van Den Bulcke and Halsberghe (1985) found that research and development and the technology employed were centrally controlled decisions. Young et al. (1985) confirmed that almost half of the subsidiaries claimed that R&D was decisively influenced by the parent company. In addition, the research and development involved was generally of a modification and adaptation nature, rather than research aimed at development and innovation. Hood and Young (1988) confirmed that 40 per cent of multinational subsidiaries located in the

[1] The share of world trade represented by R&D intensive sectors is rising. Moreover, international patenting activities have been growing. The number of strategic technology partnerships that crosses international borders also shows an increasing trend (Narulla and Zanfei, 2005).

British Isles conducted no activity in either research or development. Even in subsidiaries which undertook research and development, the number of people employed was small. They therefore concluded that research and development was not only centrally controlled but also centrally located. Further evidence for centralization of research and development was shown by Hu (1992), who found that research and development personnel were mostly concentrated in the home nation.

On the other hand, De Meyer and Mizushima (1989) noticed that over the years there was a significant change in the attitude of MNCs to research and development. Consistent with increased globalization, more decentralization of research and development decision-making had occurred. Globalization should result in a greater need for local technical support and therefore a greater autonomy. Ghoshal and Bartlett (1988) evaluated the linkage between subsidiary autonomy and innovation, and established that higher levels of local decision-making power not only facilitated the creation of locally-developed innovations but also their diffusion throughout the international network. Nor did local autonomy impede in the adoption of parent company innovations. Locate in Scotland (1997) found that in the case of research and development and process development, subsidiaries had at least partial responsibility in 70 per cent and 82 per cent of cases, respectively. This increase in responsibility is consistent with the findings of Papanastassiou and Pearce (1997) who argue that as global competitiveness intensifies, MNCs need to be able to respond to changing consumer demands in all major markets at an ever increasing speed. This also includes increasingly recognizing the distinctive needs of consumers in various worldwide markets. By allowing subsidiaries to become more responsive to these changing needs both the MNC as a whole and the subsidiary will benefit. The MNC can benefit from a wider scope of knowledge, while the subsidiary may profit from the increase in creative

roles devolved to the subsidiary. These benefits are unlikely to be gained if the technology inputs remain within the domain of the established technology function of the MNC, however.

The home base exploiting perspective was therefore challenged in more recent years by the observation that multinational enterprises increasingly generate new research and development outside of their home countries. Such a strategy has been described as asset seeking, host base augmenting, competence creating or technology driven. Asset-seeking strategies are driven by supply factors, such as the availability of skilled researchers, the need to monitor the technological activities of competitors, clients, universities and other research organizations, or the wish to assimilate local knowledge in the host countries (Castellani and Zanfei, 2006).

In spite of the growing body of evidence pointing to the globalization of knowledge creation and diffusion, there are a number of theoretical reasons to expect that foreign affiliates of MNCs will find it tough to take advantage of local innovativeness. First, foreign affiliates face a higher fixed cost of learning due to their non-familiarity with the host country. Second, foreign affiliates are less likely to benefit from agglomeration economies and spillover effects, since they tend to be less embedded in the host economy.

MNCs are increasingly seeking complementary foreign assets and knowledge-facilitating capabilities, in order to add value to their core competitive advantages. This is particularly the case when their affiliates do become more firmly rooted in host economies. Examples of this approach indicate that foreign-owned subsidiaries typically tap into local industry in order to keep their parent company informed about leading-edge thinking (Porter, 1990; Bartlett and Ghoshal, 1986), while studies by Frost (1998)

and Almeida and Kogut (1997) show how subsidiaries draw from local sources in their innovation processes.

Hypothesis 1. The more embedded the foreign subsidiary in the local environment, the higher its research intensity.

MNCs also tend to perform more R&D in foreign locations with strong technological capabilities, and this leads to a further strengthening of indigenous R&D activities. There is an increase of knowledge seeking FDI by MNCs, because the intra-firm specialization and the related local embeddedness of know-how make it difficult to achieve international innovation processes within the MNC without participating in foreign locations. The economics of industrial and technological localization are therefore likely to be increasingly shaped by the interaction between multinational corporations and local firms. The probability of assigning R&D responsibility to an existing foreign subsidiary is therefore expected to be positively related to the relative R&D expenditure by same industry firms within the host region.

The greater the diversity of knowledge created by competitors -and the potential for more leakages- should signal a greater potential for spillovers to the focal subsidiary. Greater R&D expenditure by other firms would, on average, produce a more abundant and diverse supply of technical knowledge. Consistent with this argument, empirical studies have found that the greater the scale of R&D by other firms within the same region and industry, the greater are the returns to focal firms from their own investments in R&D (Bernstein and Nadiri, 1988; Jaffe, 1986). Thus, dispersion of R&D

across a larger number of firms is likely to result in greater diversity in the technology projects being pursued and, as a result, in the content of the technical knowledge that could spillover.

Although every firm would do its best to guard its own intellectual property and minimize outgoing spillovers, these efforts at leakage prevention are less than perfect (Almeida and Kogut, 1999; Jaffe, Trajtenberg and Henderson, 1993). For instance, more external cooperation in R&D as opposed to intramural R&D by other firms may affect the foreign subsidiaries' likelihood of spillovers despite other firms' efforts to prevent unintended leakage. As such, a higher dispersion of external R&D expenditure across firms will lead to a higher probability that the focal subsidiary will be able to access external spillovers.

Hypothesis 2. Higher external R&D as opposed to intramural R&D by other firms will increase the likelihood of spillovers and reduce the research intensity of foreign subsidiaries.

Bustos (2005) investigates the link between technology adoption and firms' export status both empirically and theoretically. Her theoretical model predicts that, in the presence of fixed costs to enter the export market and fixed costs of technology adoption, only firms that are able to export can overcome the fixed costs associated with the introduction of a new technology. Firms that export have access to a larger market, allowing them to recover the costs associated with its research efforts more easily.

Bustos confirms these predictions using data on the manufacturing sector in Argentina during the 1990s.

Moreover, when affiliates start exporting their products, they require more sophisticated knowledge and technology than the domestic supply oriented affiliates in order to customize their products to suit export markets. Therefore, the affiliates that export a large portion of their products are inclined to spend more money not only for support-oriented R&D but also for knowledge sourcing R&D.

Hypothesis 3. A higher propensity of affiliate firms to export increases their R&D intensity.

3. Data and preliminary facts

The empirical analysis presented in the next section is carried out using three different data sources. We will discuss each of them in turn.

Innovation data

The innovation data are taken from the Community Innovation Survey, wave 4 (CIS4) for Belgium and were obtained from the Belgian Science Policy[2]. The sample of CIS4-firms consists of 3,322 firms. Firms with missing identification number (VAT) are omitted (1 firm), as well as firms with exports amounting to more than 100 percent of total sales in 2004 (1 firm). For ten firms no matching annual accounts information could be obtained (cfr. infra), reducing the sample to 3220 enterprises. Of these firms,

[2] We would like to thank Manu Monard, Peter Teirlinck and the CFS-STAT Commission for allowing us to access the data, for their hospitality during visits there and for answering questions related to the data.

198 were subject to a merger, or acquisition by another company between 2002 and 2005 and are hence deleted from the sample. Of the remaining 2805 firms, 1206 firms introduced an innovation, of which 374 firms are foreign innovators. Hence, the final sample size amounts to 374 firms. The CIS4 questionnaire pertains to the years 2002 to 2004. However, all financial information (e.g. R&D expenditures) is only reported for 2004. Hence, the data are cross-sectional in nature.

Teirlinck (2005a) has shown, using data from the biannual OECD R&D survey, that the dominance of foreign firms in total R&D spending in Belgium is related to their sector and size distribution. Specifically, foreign firms tend to be overrepresented in certain high technology sectors, e.g. pharmaceuticals. Moreover, foreign firms tend to be large and large firms tend to spend more on R&D: they account for more than 75 percent of private R&D spending in his sample and 80 percent of the large firms are foreign-owned.

[Figure 1]

These findings are in line with the sector and size distribution shown in Figure 1 and 2. Foreign firms are overrepresented in the high-technology manufacturing sector, which includes pharmaceuticals, but they are underrepresented in high-technology services[3]. In terms of the size distribution, Figure 2 shows that foreign firms tend to be large employers; they are overrepresented in the group of firms employing at least 50 employees. We will take the size and sector distribution of the foreign firms into account in the empirical analysis below.

[Figure 2]

[3] Sectors in Figure 1 are classified according to their technological intensity using the classification of Eurostat. Appendix Table A.2 provides the breakdown of the classification into 2-digit NACE codes.

As hypothesized in section 2, foreign affiliates can overcome part of their liability of foreignness by tapping into local knowledge sources in the host country. Linkages between the multinational affiliate and clients, competitors, suppliers and other sources can improve the firm's embeddedness in the host country environment and can hence stimulate its research efforts. Knowledge sources included in the CIS questionnaire are (a) internal, (b) market sources: suppliers, competitors, clients, consultants or other commercial organization (private institutions), (c) institutional sources: universities and higher education institutes, public research institutes; and (d) other sources: conferences and trade fairs, scientific publications and professional and industry associations.

Given our interest in external knowledge sources, in what follows we will focus on the market sources and institutional sources, distinguishing between *clients, competitors, suppliers, universities* and *private* and *public research institutes*. Table 1 provides some preliminary evidence on the importance of each of these knowledge sources, distinguishing firms according to their R&D status. The knowledge source variables are dummies, equal to one if the firm values that particular source as very important in shaping its research activities. From Table 1, it is clear that firms engaging in internal R&D activities value the importance of external knowledge higher (on average), compared to the firms with no internal research activities. With the exception of suppliers, this is the case for all the external sources listed in the table.

Annual accounts data

A foreign firm with higher productivity can, ceteris paribus, free up more resources to spend on R&D compared to its less productive competitors. Hence, more productive firms are expected to spend more on R&D. Cassiman and Golovko (2007) show, for a

sample of Spanish manufacturing firms, that firms engaged in R&D stochastically dominate firms without R&D activities in terms of their productivity.

By merging the CIS4-data with annual accounts data from Belfirst (BvDEP, 2006), it is possible to calculate firm-level labor productivity for all the firms in our sample. Labor productivity is defined as net value added per employee[4]. Table 1 compares labor productivity for the group of R&D performers versus non-R&D performers among the foreign firms. Out of 374 foreign firms in the sample, 156 are firms that do not engage in R&D and 218 affiliates report positive internal R&D expenditures for 2004. From Table 1, it is clear that foreign firms engaging in R&D tend to be larger (in terms of employment), more productive and they have a higher export intensity on average, compared to firms that have no internal R&D spending.

[Table 1]

Spillover variables

According to hypothesis 2, higher external R&D within the same sector and region of the firm reduces foreign affiliates' research intensity. To the extent that external R&D is subject to a higher danger of unintended leakages of knowledge compared to internal R&D, it can be expected that external R&D spillovers will reduce firms' own R&D efforts, i.e. there is substitution between firms' own research efforts and the efforts made within the same sector of activity. On the other hand, it can also be argued that spillovers resulting from internal or external R&D efforts, can act as a catalyst to firm-level R&D spending, through cooperation activities or through access of specialized knowledge, as was the case for the external knowledge sources (cfr. supra).

[4] Variables are defined in Appendix A.

To identify spillovers, we use data from the Community Innovation Survey, wave 3 (CIS3) for Belgium. This implies that the spillover variables for internal and external R&D are lagged one period (4 years), in order to avoid a simultaneity bias. Specifically, internal R&D spillovers are defined as the sum of total internal R&D in a certain sector, divided by the sales of that sector. External spillovers are defined analogously using the sum of external R&D in a particular sector.

The two spillover variables, which are defined at the two-digit sector (NACE) level, are also summarized in Table 1. Firms engaging in R&D tend to be active in sectors characterized by a higher internal R&D intensity on average, compared to firms that do not engage in internal research efforts. For external R&D spillovers, there appear to be no significant differences between the two types of firms.

4. Empirical model and results

Empirical model

To gain further insights into the role of host-country knowledge flows and spillovers on foreign affiliates' internal research intensity, the following empirical model is estimated.

$$\begin{aligned} RD_i = {} & \alpha_0 + \alpha_1 \ln(Emp_i) + \alpha_2 \ln(Prod_i) + \alpha_3 Export_i \\ & + \alpha_4 SUPPLIER_i + \alpha_5 COMP_i + \alpha_6 CLIENT_i \\ & + \alpha_7 PRIVATE_i + \alpha_8 UNIV_i + \alpha_9 PUBLIC_i \\ & + \alpha_{10} INT\_SPILL_j + \alpha_{11} EXT\_SPILL_j + \sum_k \beta_k IND_k + \sum_r \beta_r REGION_r + \varepsilon_i \end{aligned} \qquad [1]$$

where

RD_i R&D-intensity of the firm, defined as total internal R&D expenditures, divided by firm turnover.

Emp_i	Firm-level employment, full-time equivalents.
$Prod_i$	Labor productivity, defined as net value added per employee of the firm.
$Export_i$	Export intensity, measured as total export value divided by sales.
$SUPPLIER_i$	Dummy equal to one if the firm values suppliers as an important knowledge source for innovation.
$COMP_i$	Dummy equal to one if the firm values its competitors as an important knowledge source for innovation.
$CLIENT_i$	Dummy equal to one if the firm values clients as an important knowledge source for innovation.
$PRIVATE_i$	Dummy equal to one if the firm values private institutions as an important knowledge source for innovation.
$UNIV_i$	Dummy equal to one if the firm values universities as an important knowledge source for innovation.
$PUBLIC_i$	Dummy equal to one if the firm values public research institutions as an important knowledge source for innovation.
INT_SPILL_j	Internal knowledge spillovers, defined as total internal R&D over sales in the firm's two-digit NACE sector.
EXT_SPILL_j	External knowledge spillovers, defined as total external R&D over sales in the firm's two-digit NACE sector.
IND_k	Sector dummies. Sectors are distinguished by their technological intensity (cfr. Appendix Table A2).
$REGION_r$	Regional dummies, NUTS1-level.

R&D intensity is a censored variable, equal to zero if the firm had no positive internal R&D expenditures in 2004. Therefore, equation [1] is estimated using a tobit model, which takes this censoring into account.

As noted in section 2, foreign firms might be able to overcome part of their liability of foreignness in innovation by tapping into local knowledge sources, thus increasing the firm's embeddedness in the host country (Frost, 1998; Almeida and Kogut, 1997). Hence, as stated in hypothesis 1, we expect foreign firms' research efforts to be positively related to their access to and use of knowledge sources in the host country. Using the CIS data, we are able to distinguish between six different sources: *suppliers, competitors, clients, private institutions, universities* and *public research institutes*.

Apart from the use of suppliers as a source of external knowledge, all of these knowledge flows were found to be more important in Table 1, on average, for foreign affiliates engaging in internal R&D, compared to the group of non-R&D performers. A priori it is hard to predict which of these knowledge sources will be more important as a determinant of foreign firms' research intensity.

As stated in hypothesis 2, in addition to access to host-country knowledge sources, multinational firms' allocation of research efforts is expected to depend positively on the potential for interaction and cooperation with other multinational and local firms within its sector (Bernstein and Nadiri, 1988). To empirically test this hypothesis, equation [1] includes an internal R&D spillover term, defined as internal R&D over sales of the two-digit NACE sector the firm is active in. To the extent that higher research efforts within the sector are complementary to the firm's own R&D efforts, foreign affiliates are

expected to increase their own research spending in response to an increase in R&D spending within its sector.

On the other hand, in the absence of formal cooperation, host country firms will make an effort to limit the unintended transfer of knowledge to other same-sector firms. In this context, it is likely to be more straightforward for firms to protect the knowledge generated within the firms' boundaries, while it is relatively harder to guard the knowledge flows resulting from its external R&D efforts (Hypothesis 2). Equation [1] therefore includes an additional spillover term, defined as the sum of external R&D spending over sales in the firm's sector of activity. Unlike internal R&D efforts, which are likely to foster cooperation among firms, the knowledge flows resulting from external R&D efforts are hypothesized to act as a substitute for foreign affiliates' own research efforts.

Firms engaging in exports have access to a larger market, allowing them to recover the costs of R&D more easily (Bustos, 2005). Moreover, to the extent that different export markets differ in terms of their tastes and requirements, exporting activities are also likely to increase the need for additional technology and knowledge. We therefore expect foreign affiliates' research intensity to be positively related to their export intensity.

In addition to these variables, firm size, labor productivity and sector dummies are included as additional control variables in [1].

Empirical results

Table 2 summarizes the results of estimating [1] for the full sample of foreign affiliate firms that have filled out the full CIS questionnaire (innovators, 374 firms). Values in the table are marginal effects, referring to the expected value of the dependent variable, conditional on being positive. Marginal effects are evaluated at the mean of the independent variables, for dummies they reflect a change from zero to one.

[Table 2]

Table A.1. in the appendix reports the correlation between the different independent variables. As can be seen in the table, correlations between the variables included in [1] are generally low. Apart from the correlation between public research institutes and universities, which amounts to 0.59, none of the correlations amount to more than 0.50.

As expected, foreign affiliates' research intensity is positively related to its size, defined as the number of employees. This result is consistent with the notion that large firms operate on a larger scale, making it easier for them to recover the investment associated with R&D. Similarly, firms with higher labor productivity can be considered more efficient, allowing them to produce more output with the same amount of employees, hence enabling them to overcome the costs associated with R&D more easily. Contrary to expectations, the marginal effect for labor productivity is not significant in table 2. However, if we do not control for firm size (unreported, available from the authors upon request), we find labor productivity to have a positive and significant effect on affiliates' R&D intensity.

Out of the six knowledge sources included in [1], only two are found to have a positive and significant effect on foreign firms' research spending. In particular, foreign affiliates are found to increase their own R&D spending in response to access to external knowledge stemming from *clients* and *public research institutes*. Hence, our results lend support to Hypothesis 1: local embeddedness of a firm, measured by its linkages to local knowledge sources, is found to contribute positively to firms' own R&D efforts. Interestingly, clients act as a vital knowledge source, pointing to the importance of local factors in shaping multinationals' research activities.

Apart from clients, access to public research institutes also acts as a significant driver of firm-level research intensity of foreign firms. This finding suggests an important, albeit indirect, role for the government in increasing foreign firms' research efforts in Belgium. As noted in the previous section, previous research has indicated that specific policies aimed at attracting foreign innovative activity might be less efficient compared to policies designed at fostering research activity within certain well-targeted sectors and firms (Teirlinck, 2005a). Other research has similarly shown that foreign firms spend less, ceteris paribus, on R&D compared to their domestic counterparts (Un and Cuervo-Cazurra, 2008; Van Beveren, 2008). As such, costly policies aimed solely at the attraction of foreign research spending can be considered inferior to policies aimed at increasing the research activities of these foreign firms. Therefore, our results suggest that the government has a more indirect role to play, by fostering public research infrastructure.

The results for the internal and external R&D spillovers are in line with the expectations put forward in Hypothesis 2. Foreign affiliates' internal R&D over sales ratio is shown to depend positively on the internal R&D efforts of "same industry" firms within the host country and negatively on the external R&D efforts of these firms. Higher internal R&D

efforts within the same sector enhance the opportunities for cooperation and collaboration in R&D, hence increasing the R&D intensity of the foreign affiliate; while external research activities increase the possibility of unintended knowledge transfer, hence reducing the need for firms to engage in internal research activities.

Moreover, export intensity is positively related to foreign firms' research intensity, lending support to Hypothesis 3. Exporting firms have access to a larger market, enabling them to recover the cost of research more easily. Moreover, different export markets may have different tastes and requirements, which have to be met, thus increasing the need for internal research efforts.

Compared to firms active in the low-tech manufacturing sector, and controlling for firm-level characteristics, access to knowledge sources and spillovers, only firms active in high-technology knowledge-intensive services spend significantly more on R&D. Finally, there appear to be no significant different in terms of foreign affiliates' relative R&D efforts between the different regions in Belgium (the Walloon region), after accounting for other factors that affect firms' research intensity.

5. Conclusions

This paper has focused on the research intensity of foreign subsidiaries. It has thereby specifically analyzed firm-level knowledge sources and spillovers.

First, although previous research has focused on the spillover effects that foreign MNCs can have on host country firms (Kugler 2006, Smarzynska Javorcik, 2004; Damijan et al.,

2003, 2008), this paper has analyzed the impact of host country firms' technology effort on foreign firms.

Firms tend to prevent leaking of information and technology to competitors. This effort to protect firm-level knowledge is likely to be more successful when firms' own R&D efforts are concerned, compared to the situation where part of the R&D effort is performed externally. This diverging degree of technological spillovers subsequently has a different impact on the research intensity of foreign firms. As increased internal research intensity by competitors, together with limited spillovers, throw down the gauntlet; this increased technological threat increases the research intensity of foreign subsidiaries. In a similar, yet contradictory way, the increased use of external research and development by competitors leads to increased spillovers, which, in turn, leads to a reduced need to carry out research and development by foreign subsidiaries themselves.

Second, the results show that subsidiaries that are better embedded in the host country environment demonstrate higher research intensity. This paper has shown, in particular, that higher client knowledge sources and better access to public research institutes are instrumental in significantly increasing subsidiaries' research efforts.

For governments this means that public research institutes have an important role to play in stimulating foreign firms' research and development efforts. As most European countries are struggling to reach the Lisbon agenda target of spending 3 per cent of GDP on R&D expenditures, increasing the public research institutes' efforts could go a long way in achieving their goal. It would not only directly increase non-business

expenditures on R&D; it would also indirectly significantly increase business expenditures on R&D.

For multinational firms the results show that more research autonomy goes hand in hand with more market autonomy. Firms seem to be demonstrating more research intensity as they are getting more in sync with their clients. Instead of selling what they can make, firms seem to be increasingly making what they can sell.

However, affiliates that become overly embedded in their host country environment may be viewed as confined by headquarters, losing credibility within the organization and being cut off from future developments or flows of strategic resources and knowledge (Porter, 1990). Being more autonomous does not necessarily entail an improved role in the multinational network (Mudambi, 1999). In order to avoid a research effort that is detached or incommensurate from the rest of the multinational, more research intensive affiliates are exporting more. The results show that export intensity significantly improves research intensity. Hence, it seems that, in order to avoid research efforts by subsidiaries for the benefit of the local economy rather than for the benefit of the multinational group, more intensive research affiliates are given more market scope.

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Appendix A: Data and definitions

Sample selection

To identify foreign subsidiaries of foreign firms, ownership information available in the CIS questionnaire is used. Specifically, firms are asked whether they are part of a group, and if they are, where the headquarters of that group is located. Only firms that are part of a group with headquarters located outside Belgium, were selected (700 firms). Moreover, since only firms that report ongoing or abandoned innovation activities are required to fill out the full questionnaire, we only retain those firms with reported innovation activities between 2002 and 2004 (374 firms).

Dependent variable

R&D expenditures	Intra-mural expenditures on research and development in 2004, in thousands of euros. Specific question from the CIS-survey: "Please estimate the amount of expenditure on intramural R&D (including personnel and related costs) as well as capital expenditures on buildings and equipment specifically for R&D in 2004 only."
Sales	Turnover in 2004, thousands of euros.

The dependent variable is defined as internal R&D expenditures over sales, its value ranges between 0 and 1.

Source: Community Innovation Survey Belgium, wave 4.

Independent variables

Employment	Number of employees in 2004, full-time equivalents.
	Source: Community Innovation Survey Belgium.
Export intensity	Share of exports in sales, value between 0 and 1.
	Source: Community Innovation Survey Belgium.
Labor productivity	Net value added per employee, thousands of euros.
	Source: BvDEP (2006).

Firm-level knowledge sources

Firms are asked in the CIS questionnaire to value the importance of several knowledge sources to their innovation activities. Specifically, the question reads: "During the three years 2002 to 2004, how important to your enterprise's innovation activities were each of the following information sources? (Please identify sources that provided information for new innovation projects or contributed to the completion of existing innovation projects.)". Firms are asked to mark the importance of each of the knowledge sources according to the following scale: 0 = not important; 1 = low importance; 2 = medium importance; 3 = high importance.

The knowledge source variables used in the empirical analysis have been recoded to dummy variables, equal to one if a firm has valued that particular source as being highly important. We include six different knowledge sources: Clients, Competitors, Suppliers, Private institutions, Public research institutes and Universities.

Industry spillover terms

Spillovers are calculated using data from the Community Innovation Survey, wave 3 for Belgium. The CIS3-data contains information on about 2,100 firms. To obtain a measure of internal and external R&D spillovers by sector, we sum total R&D expenditures in that sector of all firms who participated in the questionnaire and divide this number by their total sales. This leads to the following definitions for the internal and external spillover terms:

Internal R&D spillovers	Internal R&D over sales ratio within each 2-digit NACE sector, based on CIS3-data. Definition of internal R&D in the CIS-questionnaire: "Intramural (in-house) R&D: creative work undertaken within your enterprise to increase the stock of knowledge and its use to devise new and improved products and processes (including software development)."
External R&D spillovers	External R&D over sales ratio within each 2-digit NACE sector, based on CIS3-data. Definition of external R&D in the CIS-questionnaire: "Extramural R&D: same activities as above, but performed by other companies (including other enterprises within your group) or by public or private research organisations and purchased by your enterprise."

Table A.1.: Correlation matrix

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
[1] ln(Employment)	1.00										
[2] ln(Labor productivity)	0.03	1.00									
[3] Export intensity	0.26	0.00	1.00								
[4] Internal	0.16	0.06	0.05	1.00							
[5] Supplier	0.00	-0.14	0.02	0.06	1.00						
[6] Competitor	0.03	0.06	0.02	0.08	0.15	1.00					
[7] Client	0.10	0.04	0.18	0.11	0.09	0.35	1.00				
[8] Private insititutions	0.05	-0.03	0.01	0.11	0.13	0.11	-0.03	1.00			
[9] Universities	0.06	0.00	0.03	0.07	0.08	0.11	-0.02	0.37	1.00		
[10] Public	0.04	-0.01	-0.02	0.11	0.05	0.28	0.05	0.44	*0.59*	1.00	
[11] Internal R&D spillovers	0.01	0.13	-0.07	0.07	-0.13	-0.06	-0.02	0.01	0.08	0.07	1.00
[12] External R&D spillovers	-0.10	-0.01	-0.12	0.03	-0.06	-0.02	0.00	0.03	0.09	0.15	0.42

Correlation matrix of independent variables. Variables are defined in Appendix A.

Table A2: Sector Classification According to Technology Intensity and Knowledge Intensity					
Manufacturing			Services		
Sector	NACE	Description	Sector	NACE	Description
High-technology manufacturing	244	Pharmaceuticals	*Knowledge-intensive services*	61	Water transport
	30	Office machinery - computers		62	Air transport
	32	Radio, TV, communication equipment		64	Post and telecommunications
	33	Medical, precision, optical instruments		65	Financial intermediation
	353	Aircraft - spacecraft		66	Insurance and pension funding
	24	Chemicals, excl. pharmaceuticals		67	Ancilliary financial activities
	29	Machinery and equipment		70	Real estate activities
	31	Electrical machinery		71	Renting activities
	34	Motor vehicles		72	Computer and related activities
	35	Other transport equipment (excl. 351 & 353)		73	Research and development
Low-technology manufacturing	23	Coke, refined petroleum products		74	Other business activities
	25	Rubber and plastic		80	Education
	26	Nonmetallic mineral products		85	Health and social work
	27	Basic metals		92	Recreational activities
	28	Fabricated metal products	*Less-knowledge-intensive services*	50	Wholesale/retail trade of motor vehicles
	351	Building/repairing of ships and boats		51	Wholesale trade
	15	Food and beverages		52	Retail trade
	16	Tobacco		55	Hotels and restaurants
	17	Textiles		60	Land transport
	18	Clothing		63	Supporting transport activities
	19	Leather (products)		75	Public administration, defense
	20	Wood (products)		90	Sewage and refuse disposal
	21	Pulp, paper (products)		91	Activities of membership organizations
	22	Publishing and printing		93	Other service activities
	36	Furniture		95	Activities of households
	37	Recycling		99	Extraterritorial organizations and bodies
Source: Eurostat.					

Figure 1: Comparison of all innovators against foreign innovators, by sector

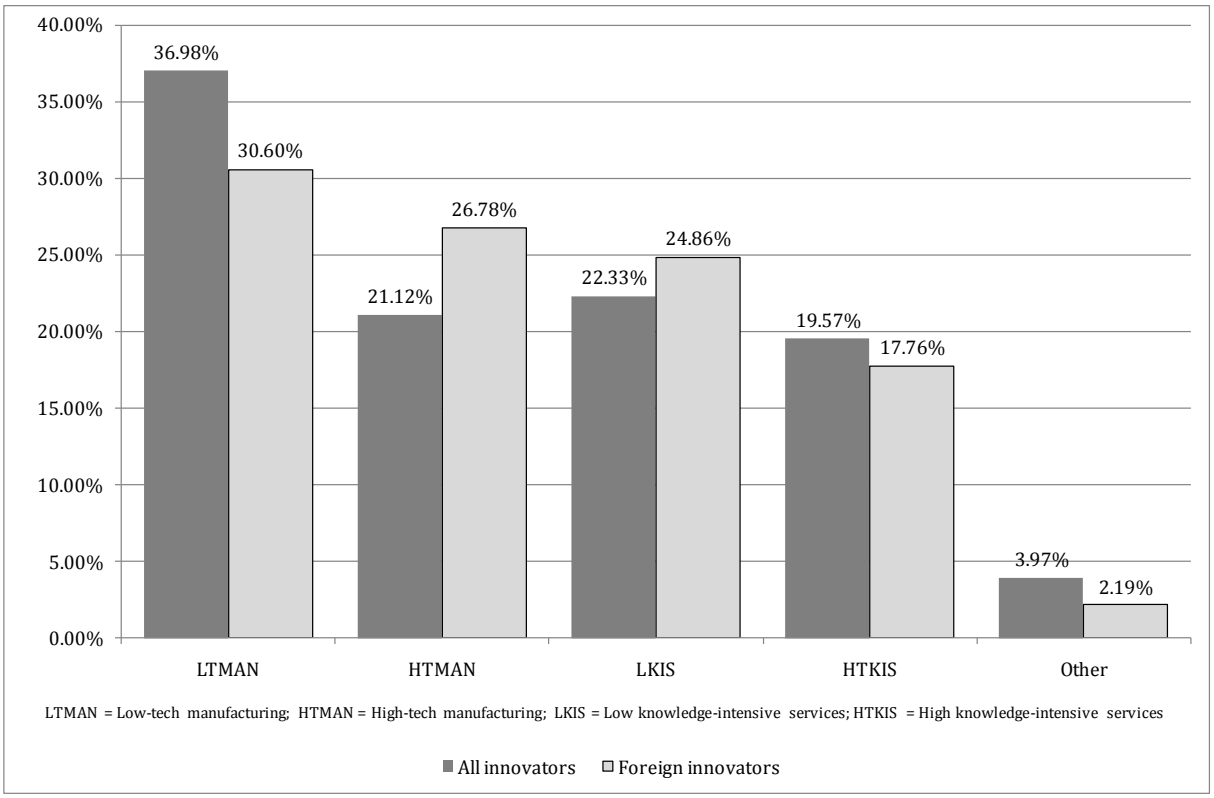

Figure 2: Comparison of all innovators against foreign innovators, by size

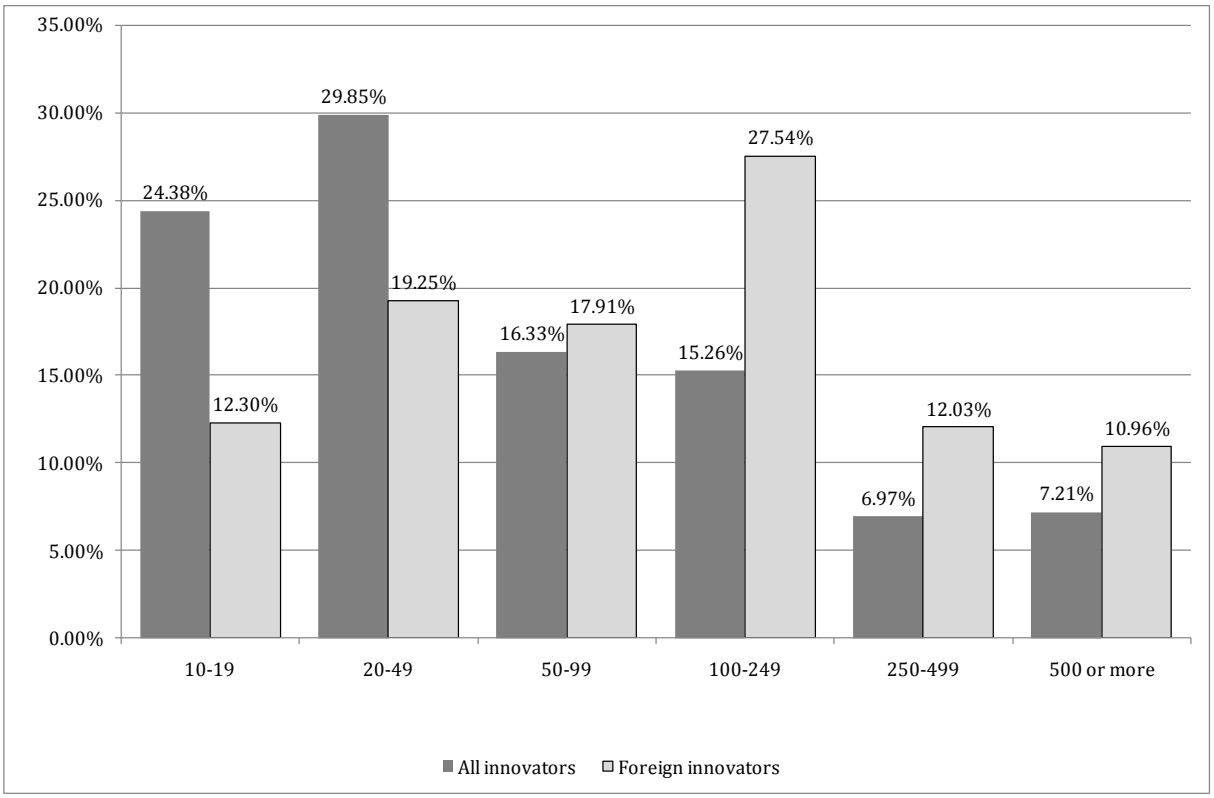

Table 1: Summary statistics		
Variable	Non-R&D performers	R&D performers
Number of firms	156	218
	(41.71%)	(58.29%)
Employment	222.49	275.31
(Number of employees, full time equivalents)	(727.60)	(408.99)
Labor productivity	92.05	117.68**
(Net value added/employee, € x 1,000)	(60.09)	(177.70)
Export intensity	32.59	56.94***
(Exports/sales)	(37.01)	(40.94)
Supplier knowledge sources	0.28	0.27
	(0.45)	(0.44)
Competitor knowledge sources	0.17	0.24*
	(0.38)	(0.43)
Client knowledge sources	0.29	0.56***
	(0.46)	(0.50)
Private institiutions knowledge sources	0.06	0.09
	(0.25)	(0.29)
Universities knowledge sources	0.03	0.10***
	(0.18)	(0.30)
Public knowledge sources	0.00	0.05***
	-	(0.21)
External R&D spillovers	0.02	0.02
	(0.06)	(0.07)
Internal R&D spillovers	0.01	0.03***
	(0.03)	(0.05)

Values are means (standard deviations). Variables are defined in Appendix A.
Sigfnificance levels refer to one-tailed t-test of difference in means.
* p < 0.10, ** p < 0.05, *** p < 0.01.

Table 2: Regression results	
Variables	ME [se]
ln(Employment)	0.035*
	[0.020]
ln(Labor productivity)	-0.03
	[0.040]
Export intensity	0.003***
	[0.001]
Supplier knowledge sources	-0.047
	[0.055]
Competitor knowledge sources	-0.075
	[0.062]
Client knowlegde sources	0.248***
	[0.050]
Private institution knowledge sources	0.118
	[0.103]
University knowledge sources	0.000
	[0.111]
Public knowledge sources	0.431***
	[0.126]
Internal R&D spillovers	2.568***
	[0.830]
External R&D spillovers	-0.961*
	[0.529]
High-tech manufacturing dummy	0.079
	[0.066]
HT knowledge int. services dummy	0.211**
	[0.102]
LT knowledge int. services dummy	-0.088
	[0.072]
Other sectors	-0.103
	[0.179]
Brussels region dummy	0.098
	[0.082]
Flemish region dummy	0.033
	[0.058]
N	374
Pseudo R-squared	0.147

Dependent variable: Internal R&D over sales ratio. Tobit estimation with censoring at 0 and 1. Values are marginal effects based on the expected value of the dependent variable, conditional on being positive. Marginal effects are evaluated at the mean of the independent variables. For dummies, the marginal effects refer to a change from 0 to 1. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.