Local, global, and internal knowledge sourcing: the trilemma of foreign-based R&D subsidiaries

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Abstract

Multinational Enterprises (MNEs) develop and sell their products and services in a global market, but also have the ability to source knowledge from local, global and intra-MNE networks. We argue that sourcing knowledge from each of the three networks is contingent upon factors, such as the strategic choice made by the headquarters about the role of the research and development (R&D) subsidiary, the scientific richness of the host location, and the institutional (i.e. IPR - Intellectual Property Rights) distance between the home and host locations. We test our hypotheses on a dataset of 89 foreign-based R&D subsidiaries of Fortune 500 MNEs. Our results indicate that R&D subsidiaries with support lab mandates are less likely to use host and internal (intra-MNE) sources of knowledge and more likely to use the home location's sources of knowledge. Internationally independent labs are less likely to source knowledge from internal networks. Our findings show also that the scientific capability and availability of a technically skilled workforce in the host location is associated with the R&D subsidiary's use of local, rather than internal knowledge sources. Finally, we find that weak IPR spurs the use of local knowledge sources, suggesting a role for technological spillovers.

Keywords: Knowledge sourcing; Multiple embeddedness; Headquarters-subsidiary relationship; Subsidiary Role; Seemingly unrelated regression

1. Introduction

New product development is an important facet of the Multinational Enterprise (MNE) strategy, and as a topic is increasingly researched in the international marketing (e.g. Craig & Hart, 1992; Urban & Hauser, 1993; Zirger & Maidique, 1990) and international business (e.g. Griffith, Harmancioglu & Droge, 2009; Subramaniam, 2006; Subramaniam & Venkatraman, 2001) literatures. Scholars of international marketing primarily stress the importance of marketing and industrial (product) design to the development and commercial success of new products (Kahn, 2001; Kotler, 2003; Veryzer, 2005). They focus also on the consumer (user) integration in the process and overall success of new product development (Hoyer, Chandy, Dorotic, Krafft, & Singh, 2010; Piller & Walcher, 2006; Veryzer & Borja de Mozota, 2005).

Scholars in the field of international management study the "transnational new product development" process (Subramaniam & Venkatraman, 2001; Takeuchi & Porter, 1986) and the importance of MNEs' capability to efficiently transfer and utilize all the knowledge sources within the firm's network of knowledge (Subramaniam & Venkatraman, 2001). This literature recognizes that a primary objective of establishing foreign-based MNE research and development (R&D) subsidiaries is engagement in (transnational) new product development via effective knowledge transfer and generation. The relationship between federated MNE units (i.e. HQ and subsidiaries) and the knowledge that is transferred between them is significant for global new product development and market launch (Ambos, 2005; Lahiri, 2010; Yamin & Andersson, 2011).

New product development technology consists of two parts: generic technology which is held by the headquarters and often protected by patents, and adaptive R&D which usually resides in the overseas subsidiary which works closely with local marketing teams in order to optimize the product for the host country conditions. The international R&D subsidiary is usually responsible for the adaptation/standardization of products for the local context (Subramaniam & Hewett, 2004). The international business literature describes such R&D subsidiaries as 'Home-Base-Exploiting' following Kuemmerle's (1997) typology, or 'Competence-Exploiting' in line with Cantwell and Mudambi (2005).

Subsidiary capability develops with the firm's embeddedness in the host context and the increasing confidence of the parent company that the subsidiary can assume more responsibility and undertake more activities in the value chain that will benefit the entire MNE network (Andersson & Forsgren, 1996). R&D subsidiaries make use of the host environments' scientific and technological endowments to develop their skills and become a valuable source of knowledge for the whole MNE network. R&D subsidiaries undertaking this type of knowledge-generating function are described as 'Home-Base-Augmenting' (Kuemmerle, 1997) or 'Competence-Creating' (Cantwell & Mudambi, 2005). Over time, as the MNE grows and establishes more subsidiaries it can benefit from a finer division of innovative labour within its R&D subsidiary network. Unique R&D subsidiary capabilities in one location also enable the transfer of knowledge and practices among different contexts and different subsidiaries (Minbaeva, Pedersen, Björkman, Fey & Park, 2003). The sources of knowledge that an international R&D subsidiary can exploit also become more diverse over time and the benefits derived from this knowledge sourcing extend also to the parent thus creating a virtuous circle of competitive advantage.

International MNE subsidiaries currently are generating more innovations and more patents than in the past. The empirical evidence shows that multinational patenting in new regions (e.g. emerging markets such as India and China) has increased (Athreye & Prevezer, 2008; Chen, 2008; Liu & Chen, 2012). These new regions are also large final markets and there is considerable evidence that location in a large market and being close to customers is an important motive for the internationalization of R&D to several regions such as China, India and Eastern Europe (Gao, 2003; Kumar, 2001). Fors (1996) and UNCTAD (2005) suggest that MNEs' offshore R&D is often located close to their largest overseas production facilities. Also, in several services and digital services sectors, firms are keen to reduce product development time by spreading their R&D across different time zones to enable 24-hour operation. This is resulting in a large proportion of co-invented patents involving inventors from various countries, suggesting higher intra-MNE collaboration and transfer of knowledge from other parts of the MNE to the newly established subsidiaries.[1]

These trends show, first, that MNEs are increasingly operating R&D facilities in multiple geographic regions and, second, that different sources of knowledge are being utilized simultaneously. However, and despite the increasing globalization of R&D, we have scant knowledge on how the R&D subsidiary chooses among different

[1] Co-invention is facilitated by greater exploitation of Information and Communication Technologies (ICT), but it also requires knowledge synergies or the possibility for knowledge exploitation.

sources of knowledge on new product development, in the external and internal environments.

This paper examines the trilemma facing foreign-based R&D subsidiaries in relation to their knowledge sourcing activities. We examine the factors that influence the choice of one form of knowledge sourcing over another. We argue that the extent to which an R&D subsidiary sources (more or less) knowledge from the global, local or internal knowledge network, is contingent on the strategic choice made by the MNE HQ (i.e. how much it is related to the R&D subsidiary's mandate) as well as the environmental/institutional characteristics of the host and home locations (i.e. scientific richness of the host location, Intellectual Property Rights (IPR) distance between the home and the host locations).

Our study contributes to work on the factors influencing different forms of knowledge sourcing and offers some implications for managerial and policy practice. While previous research focuses on the factors shaping the exploitation of either internal or external sources of knowledge and/or knowledge transfer (e.g. Menon & Pfeffer, 2003), we know little about what determines the potential simultaneous use of external home, external host, and internal knowledge sources. Thus, our research contributes to the extant literature by proposing and examining empirically a more concrete and holistic model which considers all possible forms of knowledge sourcing (i.e. internal, external home, and external host) simultaneously.

For managers, our framework and empirical methodology provides guidance on when to exercise leverage or arbitrage in the location of R&D activities based on the location-specific characteristics of the home and host locations and the knowledge resources accessible via the MNE's network of subsidiaries. For policy makers it provides guidance on whether incentives designed to attract research-intensive foreign direct investment (i.e. international R&D subsidiary) will transfer technology and knowledge through local linkages.

The remainder of the paper is organized as follows. Section 2 discusses the conceptual basis of our arguments and the three types of subsidiary knowledge sources. It draws on the literature to derive propositions about the factors associated with each type of knowledge sourcing. Section 3 describes the methodology, the data and the survey. Section 4 presents the empirical findings. Section 5 discusses these findings and the research contributions, and outlines the theoretical and managerial implications of this research and some of its limitations. Section 6 concludes the paper.

2. Theoretical framework and formulation of hypotheses

2.1. The multiple network embeddedness of the R&D subsidiary

In addition to its own resources, the R&D subsidiary can draw on two other sources of knowledge. These knowledge sources - MNE network (HQ and affiliate units) and host location (environment) in which the R&D subsidiary operates - are crucial for the subsidiary's knowledge generation and innovation performance. This has led international business scholars to distinguish between the R&D subsidiary's *internal* and *external* environments (Almeida & Phene, 2004; Ambos, 2005; Phene & Almeida, 2008). From a social network perspective, this type of engagement in two types of knowledge environment simultaneously, has been described by the academic community as 'dual embeddedness' (Figueiredo, 2011; Narula & Dunning, 2010; Tavares & Young, 2005) or 'multiple embeddedness' (Meyer, Mudambi, & Narula, 2011).

From the R&D subsidiary's perspective, internal knowledge sourcing refers to the MNE subsidiary's sourcing of technical knowledge from the network of affiliated subsidiaries and the parent company. This is measured usually by the frequency of the subsidiary's interaction with sister and parent units. The notion of external knowledge sourcing is strongly related to the MNE's 'subsidiary embeddedness' (Andersson & Forsgren, 1996, 2000; Andersson, Björkman, & Forsgren, 2005) and the subsidiary's external 'technical embeddedness' (Andersson, Forsgren, & Holm, 2001, 2002). Embeddedness refers typically to closeness of relationships and reciprocal adaptation of activities between the subsidiary and its external environment of suppliers, customers and government; technical embeddedness refers to the relationships typical of product development, viz. relationships with local universities, public sector labs and research contractors. Several studies focus on R&D subsidiaries' external and internal relationships and the factors associated with them (e.g. Almeida & Phene, 2004; Blanc & Sierra, 1999; Lee, Lee, & Pennings, 2001; Song, Asakawa, & Chu, 2011; Sumelius & Sarala, 2008; Yamin & Andersson, 2011) and find that subsidiaries that straddle both relationships are more likely to be successful innovators compared to those that depend on only one type of knowledge sourcing.

Studies in the technology management tradition concentrate on the distinction between external environment to external home (i.e. location of the parent company), and external host (i.e. location of the foreign-based subsidiary) (Criscuolo, 2009; Criscuolo, Narula, & Verspagen, 2005; Le Bas & Sierra, 2002). They assume that home country advantages have a prolonged influence and are likely to be strategic type R&D resources. This notion implies two types of external knowledge sources related to the home and the host countries knowledge environments.

This multiple knowledge sourcing choice can be perceived as a major advantage for the MNE (due mainly to the fact that the MNE can simultaneously trade-off and/or complement knowledge and resources) and its R&D subsidiaries. At the same time, this multiple sourcing risks becoming a double-edged sword since the business opportunities it provides are accompanied by several operational challenges for the MNE (Meyer et al., 2011). These issues may work to limit how much the subsidiary uses these three sources of knowledge. In the following sections we review the literature and highlight those factors that are likely to be associated with the subsidiary's use of a particular knowledge source.

2.2. Factors associated with R&D subsidiary's use of knowledge sources

2.2.1. The mandated role of R&D subsidiaries

The mandated role of the R&D subsidiary is a strategic choice made by the parent. We use a typology proposed by Hood and Young (1982) and Pearce (1989, 1994), which identifies three different types of international R&D subsidiaries.[2] The first type is the *Support Laboratories (SLs)*, whose mandate is focused on adapting existing products and processes to local conditions. The second type of R&D activity is conducted by *Locally Integrated Laboratories (LILs)* whose mandate is to coordinate closely with various other functional subsidiaries (marketing, production) in the subsidiary's local environment in order to develop or enhance products to suit local needs and scope. The third type of R&D subsidiary is the Internationally *Interdependent Laboratory (IILs)*, which have no systematic connection with the MNE's production units and are responsible for working with other independent, global networks to create new product and process patterns. Thus, *SLs* and *LILs* are

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[2] There are several, closely related typologies which are reviewed in Batsakis (2013).

oriented toward adaptation and improvement of existing products and their distribution in the host market, while *IILs* are more independent research units engaged in novel research.

External technical embeddedness in the host country is shown to be positively related to a subsidiary specific role within the MNE (Andersson, 2003; Andersson et al., 2001; Andersson & Forsgren, 2000), which means that the level of technical embeddedness with the host environment is positively affected by the specific role (either R&D- or purchasing-driven) assigned to the laboratory by its HQ. Although these empirical studies do not provide any information on the impact of the specific type of R&D subsidiary on the level of its knowledge sourcing from the external network, it is generally assumed that the external (host) network orientation of the R&D subsidiary is associated with the R&D subsidiary role.

Although we have no empirical evidence on the impact that being a particular type of the R&D lab has on the form and level of knowledge sourcing, some research has examined the impact of the type of R&D lab on other aspects of R&D management. Ambos and Schlegelmilch (2007) focus on the impact of the R&D unit mandate on three forms of management control. They find that R&D units operating as *LILs* and *IILs* are positively associated with centralization, which means that, compared to R&D units operating as *SLs* these units are strongly tied to the internal MNE network. Similarly, Nobel and Birkinshaw (1998) show empirically that R&D units operating as *SLs* and *LILs* are more likely to interact with the internal corporate network while *IILs* are likely to have strong communication channels with both external and internal knowledge sources.

Recent empirical research conducted by Manolopoulos, Dimitratos and Sapouna (2011) on R&D subsidiaries based in Greece, identify a strong positive relationship between *IILs* and subsidiary scientists' cross-border visits, which suggests that R&D labs operating as *IILs* are more likely to search for knowledge from multiple locations. In another study based on the same dataset, Manolopoulos, Söderquist and Pearce (2011) show that R&D personnel employed in *SLs* are likely to undertake assignments for the parent MNE laboratory than for another independent R&D facility in the host location. They show also that *IILs'* R&D personnel are likely to conduct research for another host country's independent research facility. Indeed, R&D employees in *IILs* have more autonomy compared to employees working in the other two types of R&D labs and, consequently, they are not very closely linked to the MNE's internal knowledge sources (Pearce & Papanastassiou, 1997).

While *IILs* seem also to be connected to the host country's knowledge sources, there is an argument that, in order for the MNE to harvest maximum gains from the R&D activities conducted abroad, the MNE's R&D function needs to be closely linked into the parent country's network (Criscuolo, 2009). *IILs* are endorsed by the HQ and have heavier research responsibilities than the two other types of R&D units. It is likely that the original research mandates of *IILs* ensures their close links with the home external network since the tacit knowledge and people-specific elements of new technological research and strategic considerations will sensitize the firm also to potential technology leaks. Based on our review, we hypothesize that:

H1a. International R&D subsidiaries acting as SLs are likely to exhibit greater home country and internal knowledge sourcing and less host country knowledge sourcing.

H1b. International R&D subsidiaries acting as LILs are likely to exhibit greater host country and internal knowledge sourcing and less home country knowledge sourcing.

H1c. International R&D subsidiaries acting as IILs are likely to exhibit greater host country knowledge sourcing and less internal and home country knowledge sourcing.

2.2.2. Host location's science and technology endowments

The above hypotheses assume that the R&D costs are the same in each location. In reality, this will not be the case, and the costs of conducting R&D have to be evaluated against the host country's location specific advantages, which stem from their scientific resource and institutional endowments. Several studies emphasize the importance of location-specific endowments including accumulated stocks of technological knowledge in the host location, and large pools of scientific and technological labour (e.g. Cantwell & Mudambi, 2000; Cantwell & Piscitello, 2002; Dachs & Pyka, 2010; Demirbag & Glaister, 2010; Groh & von Liechtenstein, 2009; Lewin, Massini, & Peeters, 2009; Narula & Guimón, 2010; Sachwald, 2008; Saggi, 2002; Varsakelis, 2001, 2006). It is generally argued that technological excellence, highly qualified labour and business friendly institutions contribute to a strong national system of innovation which will attract MNEs' R&D investments. Thus, the existence of scientific capability and strong institutions in the host location are directly related to the volume and quality of R&D undertaken by the subsidiary (Davis & Meyer, 2004).

In science- and technology-rich contexts, the R&D subsidiary will tend to establish stronger network ties with the host country’s knowledge environment (compared to the home country’s knowledge environment) in order to benefit from potential location specific advantages. These strong local ties to scientific institutions may be detrimental to the strength of the R&D subsidiary's ties with the MNE’s internal network. They may generate a substitution effect which allows the R&D unit to replace a certain level of internally generated knowledge stock with an equivalent amount from the host location. Hence, we hypothesize that:

H2. The richer the host location's scientific resources, the more (less) the amount of knowledge sourced from host (home and internal MNE) knowledge sources.

2.2.3. IPR distance (between host and home location)

The traditional view of the relationship between IPR protection and knowledge transfer implies that knowledge spillovers, information leakages, macroeconomic instability and weak intellectual property protection can represent substantial costs for MNE R&D in foreign locations. A strong IPR regime is a positive determinant of the attractiveness of technology investment and determines whether or not R&D facilities will be established (Kumar, 1996; Narula & Guimón, 2010; Saggi, 2002). In addition, Branstetter, Fisman and Foley (2005) show that in the case of US MNEs strong IPR regimes are likely to stimulate greater technology transfer to the subsidiary.

Firms may be unwilling to establish R&D facilities in regions with weak IPR regimes. Zhao (2006) argues that in this case, MNEs will practise task partitioning in order to avoid losses due to technological spillovers. Zhao provides evidence of this in the case of emerging economies with weak intellectual property regimes. This suggests greater internal knowledge sourcing through collaborative links with parent and sister affiliates, rather than with external knowledge sources.

However, a very strong IPR regime in the host location is likely to facilitate collaboration between local actors and international R&D subsidiaries. Blomstrom and Kokko (2003) argue that knowledge dissemination occurs usually through staff inter-firm mobility and frequent liaisons between the lab and its external network - the same factors that are associated with more intensive host knowledge sourcing. If the

IPR regime in the host location is sufficient to guarantee safety and formality among the actors involved in a collaboration, it can be expected that knowledge sourcing from the host location will be higher. Accordingly, we formulate the following hypothesis:

H3a. The stronger the IPR protection regime in the host country (compared to the home country), the less (more) knowledge will be sourced from the home and internal (host) knowledge network.

On the other hand, a stronger IPR environment in the host country could inhibit the level of knowledge sourcing from the host location. We expect this to apply to international R&D subsidiaries that intentionally relocate to clusters and geographic locations to tap into knowledge spillovers. These spillovers can be due to frequent inter-firm labour mobility among rival firms.

As noted earlier, firms locate their R&D activities in foreign locations in order to take advantage of specific science and technology resource endowments such as the availability of scientific labour. Weak IPR locations may consist of low cost scientific labour which MNEs are keen to take advantage of.

It has been shown empirically that a very strong IPR protection regime in a particular location can be detrimental to competition and welfare (Yang & Maskus, 2009). In developing countries in particular, a strong IPR protection regime can be an impediment to accessing scientific knowledge and reduce the collaboration opportunities (Forero-Pineda, 2006). This has a negative effect on knowledge transfer between the local scientific community and established firms. Thus, we conjecture that subsidiaries involved in knowledge-creating activities are more likely to source knowledge from the host location if the host country's institutional environment and, specifically, the IPR protection regime, is weaker than that in the home country. Similarly, firms will be more inclined to source knowledge from the internal network if there is a risk of such spillover effects occurring. Accordingly, we hypothesize that:

H3b. The stronger the IPR protection regime in the host country (compared to the home country), the less (more) knowledge will be sourced from the host (home and internal) knowledge network.

3. Data and methodology

3.1. Sample

The sample is based on the Fortune 500 list of firms published in 1986 when only 405 of the 500 units listed had established R&D facilities abroad, which reduced the sample to 405 industrial companies. A questionnaire was administered by mail to the existing population of international R&D units.[3] The subsidiary R&D manager was asked to respond to the survey. The number of surveys returned was 135 of which 89 were usable. Since we asked the best qualified person in the R&D unit to respond to the survey, we are confident that the responses of the R&D subsidiaries' respondents accurately reflect the relationship between the units and their counterparts. We guaranteed the anonymity of both firm and respondent.

In contrast to empirical studies based on more than one foreign R&D unit belonging to the same MNE (e.g. Kuemmerle, 1997; Nobel & Birkinshaw, 1998), our

[3] The first questionnaires were mailed in October 1988 and the last ones in June 1989; the first completed questionnaire was received in November 1988 and the last was received in August 1989. The survey questionnaire is available from the authors upon request.

survey targeted the MNEs' largest international R&D unit[4] (e.g. Casson & Singh, 1993; Pearce & Singh, 1992), whose role was to support local marketing and/or engineering activities, or to conduct advanced research through contribution to a globally integrated research programme. Although this selection strategy possibly excludes a number of MNE's R&D units which would add to and explain much of the total variation in the MNE's internationalization strategies, our selection process ensured that the foreign subsidiary investigated operates as an R&D-focused unit and not as an arm's length subsidiary which may be unrelated to the MNE's R&D activities. The detailed nature of questions included in the survey, and the coverage of home, host and internal knowledge networks make it an ideal source of data to test our conjectures.

The sample distribution is quite representative of what we know about the global research activity of MNEs in the late 1980s based on patent analysis. Patel and Pavitt (1991) identifies that the US accounts for almost the half of global R&D activity, followed by Japan and the UK. In our survey sample, R&D subsidiaries based in the US, the UK and Japan account for the 71.4 per cent of the total sample. In terms of industry division, some 75 per cent are R&D subsidiaries in the pharmaceuticals, electronics, and chemicals and petroleum industries which are among the most internationalized R&D sectors.

3.2. Measures

3.2.1. Constructing measures of external and internal knowledge sourcing

[4] The largest foreign R&D subsidiary was identified after consulting a number of the leading directories of R&D facilities and evaluating unit size according to financial and employment characteristics.

Subsidiary knowledge sourcing can be measured based either on analysis of patent data (e.g. Phene & Almeida, 2008) or on survey data and development of multi-item constructs (e.g. Foss & Pedersen, 2002). We adopt the second approach based on the questionnaire referred to above. The questions asked respondents to provide information on the frequency of the subsidiary's interaction with internal and external counterparts. The 3-point Likert-scale responses allowed respondent to evaluate the level of interaction from weak (1) to strong (3). Based on the survey instrument, we constructed the following measures of knowledge sourcing. *External Home*: this variable is based on the responses to the question: "Does any liaison exist between this R&D unit and the home country: i) research institutions; ii) universities; and iii) R&D labs of local and/or foreign companies?" These responses have a categorical-likert operationalization, ranging from 1 (no contacts reported) to 3 (regular contacts reported). We assume the more frequent the contact the more knowledge is sourced by the subsidiary from external home networks. We created a variable *External Home* based on the mean score of responses to the above question. The Cronbach's alpha for this construct is 0.65. *External Host*: the survey asked about the following: "1) Does this R&D unit give contract jobs to the following institutions in this country: i) independent research labs; ii) universities; 2) Does any exchange program of scientists exist between this unit and other local research institutions/labs? 3) Are seminars relating to ongoing research in this unit held in collaboration with other local research units/institutions? 4) Are research findings of this unit published in journals? 5) Are local independent researchers one of the most likely sources of project ideas initiated in this unit?" The Cronbach's alpha for this construct is 0.60. *Internal*: the questions used to construct this variable are: "Are the parent or other sister R&D units involved in your projects in any of the following ways? i) systematic coordination of your projects into wider programmes, ii) to bring about a major change in the direction of the project, iii) to advise on the development of a project, iv) to provide technical assistance at the request of the R&D unit". The Cronbach's alpha for this construct is 0.73.

3.2.2. Explanatory variables

Type of R&D Lab: our survey questionnaire used one of the most well-known R&D subsidiary typologies/archetypes in order to ask respondents under which type they would classify the operations of their R&D unit. Following the R&D subsidiary classification introduced by Pearce (1989), each unit was asked to categorize its activities into: *Support Laboratories (SLs):* Is the lab's role to assist production and marketing facilities in the host country and to make effective use of the parent's existing technology? *Locally Integrated Laboratories (LILs):* Does the lab's role, though predominantly oriented to the local market and/or production conditions, involve more fundamental development activity than SLs? *Internationally Integrated Laboratories (IILs):* Does the lab play a role in an integrated R&D programme coordinated by the parent or some other major laboratory? The responses to the above three questions form a categorical–likert operationalization with the relative responses being: not this type of laboratory (1), partially this type of laboratory (2), and predominantly this type of laboratory (3). *IPR distance:* this measure is calculated based on the relative IPR ratio between the host and the home R&D operation locations (Batsakis, 2016). This variable is constructed drawing on the IPR Protection Index (for 1960-1990), and the original scores of the IPR Protection Index (Park, 2008) range from 1 (weakest) to 5 (strongest). The higher the ratio between the host and home location, the stronger the intellectual and institutional environment of the host location (compared to the home location equivalent). *Local endowment:* this measure is based on the responses to the following four questions: "Which conditions or circumstances do you consider have most influenced recent decisions with regard to the development of this unit? i) a distinctive local scientific, educational or technological tradition conducive to certain types of research project, ii) presence of a helpful local scientific environment and adequate technical infrastructure, iii) availability of research professionals, iv) favourable wage rates for research professionals". The Cronbach's alpha for this construct is 0.72.

3.2.3. Control variables

We also included in the analysis a number of control variables based on variables that other studies have shown to be important. Greenfield*:* the theory suggests that acquired units are likely to be more embedded in the host country, but less embedded in the internal corporate network. We control for this relationship through a dummy variable which takes the value 1 if the subsidiary was a new installation (i.e. greenfield investment) and 0 if the subsidiary was the result of an acquisition or joint venture. Gassler and Nones (2008) show that location-specific factors, such as the geographic and cultural distance between the parent and the host country, also influence the costs of R&D. A common language and physical proximity are likely to be associated with similar public science norms and easier adaptability of the local workforce to the corporate culture of the MNE. We include variables for *Geographic Distance:* following Monteiro, Arvidsson, and Birkinshaw (2008), this variable is calculated based on the natural logarithm of the geographic distance between the parent country and the lab's host location. The distances are calculated following the great circle formula, which uses latitude and longitude of the most important city (in terms of population) or the official capital. *Cultural Distance:* in order to assess the degree of cultural distance between the subsidiary's home and host locations, we estimated the index developed initially by Kogut and Singh (1988) using Hofstede's well known indices, which was later adopted by various scholars researching the same area (e.g. Benito & Gripsrud, 1992; Shane, 1995). *Production subsidiary:* we created a dummy variable that takes the value 1 if the firm reports it is an R&D facility which is associated with a production subsidiary. As suggested by Cantwell and Mudambi (2005), we include this variable to capture technology exploitation/augmentation better. *Industry dummies*: in order to control for possible industry effects on the degree of the R&D subsidiary's knowledge sourcing, we incorporate industry sector dummies. We constructed four industry dummies each corresponding to a different industry sector (Chemicals and Petroleum, Electronics, Pharmaceuticals, and Miscellaneous). *Country dummies:* we include two country dummies for US and UK, two of the most internationalized world countries (in terms of R&D activities) in our sample.

3.3. Controlling for non-response bias and common method bias

To control in our sample for possible non-response bias, we employed two different methods. First, we compare the number of respondents to the original population, for all the geographical locations examined. We found that almost all the locations where R&D subsidiaries operate are well represented in the returned questionnaires. Second, since some questionnaires were collected after a reminder was sent to respondents, we test for possible non-response bias which might affect our sample's explanatory power negatively. To investigate non-response bias we compared the characteristics of several subsidiaries' based on the first set of responses collected, and those received after a reminder (Armstrong & Overton, 1977). A t-test shows no statistically significant difference ($p > 0.05$) between the two sets of questionnaires.

We control also for common method bias. Specifically, we test whether or not common method bias has inflated the relationships between the subsidiary questionnaire variables used in the analysis. We incorporate and apply Harman's single-factor test on the items included in the model (Podsakoff & Organ, 1986). The factor analysis extracted four factors with eigenvalues greater than 1. The first factor explains 21.12% of the total variance with an eigenvalue of 4.37, which is neither evidence of a single emerging factor, nor confirmation that this factor accounts for the majority of the variance (>50%). Therefore, we assume that the data are reliable and common method bias is not a major concern in our data analysis.

3.4. Empirical model

The principal focus of our arguments is that subsidiary knowledge sourcing in a host location to exploit new technological opportunities is determined jointly with the other forms of knowledge sourcing (i.e. within the MNE network to ensure coherence of R&D, and within the external networks in the home location of the HQ to ensure better overall control). Therefore, our estimation technique needs to account for this. In our case, the statistical implication of this determination of knowledge sourcing levels is a simultaneous structure which allows the errors across the equations to be correlated. Thus, if our dependent variables *External Home* (E_i^P), *External Host* (E_i^H) and *Internal* (I_i) are measures of the external (in the host and parent country) and internal knowledge sourcing respectively, we can write them in a Seemingly Unrelated Regression Estimation (SURE) form, such as the system of equations below:

$$E_i^P = \alpha + \beta_1 M_i + \beta_2 IPR_i + \beta_3 E_i + \beta_4 C_i + \varepsilon_i$$

$$E_i^H = \gamma + \delta_1 M_i + \delta_2 IPR_i + \delta_3 E_i + \delta_4 C_i + \zeta_i$$

$$I_i = \lambda + \mu_1 M_i + \mu_2 IPR_i + \mu_3 E_i + \mu_4 C_i + \eta_i$$

where *M* is a vector for the roles of the R&D subsidiaries (SLs, LILs and IILs), *IPR* is the IPR distance between home and host locations, and *E* denotes the richness of the host location's endowments. The vector (*C*) includes the aforementioned control variables.

SURE is the most appropriate system for estimating the model parameters since it allows Cov (ε_i, ζ_i), Cov (ε_i, η_i) and Cov (ζ_i, η_i) to be non-zero and, in this way, is an improvement on separate Ordinary Least Squares (OLS) estimates of each equation, which would be appropriate if each type of knowledge sourcing was determined independently of the others (Zellner, 1962, 1963). To validate our choice of method we estimated the three above equations using OLS. Next, we estimated the residuals deriving from each independent equation and assessed the correlation between them. The highly correlated coefficient values validate the use of the SURE methodology.[5]

4. Empirical findings

Survey data can suffer from multicollinearity between the variables and the constructed factors. In order to assess whether or not multicollinearity is an issue here, we estimate the Variance Inflation Factors (VIFs) for each coefficient in each of the examined model(s), via OLS regression estimation. All the VIF scores show values no greater than the rule of thumb of 10 (Hair, Anderson, Tatham, & Black, 1998). Thus, multicollinearity is not a problem in our model.

Table 1 shows that the dominant R&D type in our sample seems to be IILs.[6] For the level of local endowments, the descriptive statistics indicate that they are perceived to be high. Our location characteristics are drawn from well-known

[5] The OLS regression estimates and the derived residuals are available from the authors upon request.
[6] This outcome might be related to our research strategy to focus our target sample on the largest R&D subsidiary of each MNE examined.

secondary data sources, but, because we cover only 14 countries and not sub-regional units, they exhibit limited variability.

--- Table 1 goes about here ---

Table 2 reports the SURE model estimation. Hypotheses 1a, 1b and 1c test the impact of specific R&D roles on the external knowledge networks of the host and home country, and the internal MNE network. The results only partly confirm Hypotheses 1a and 1c. Specifically, SLs is negatively associated with the host country's external network (β[7] = -0.10, $p < 5\%$) and positively associated with the home country's external network ($\beta = 0.13$, $p < 5\%$). However, contrary to our predictions, we find that SLs are negatively rather than positively related to Internal network ($\beta = -0.13$, $p < 5\%$). Hypothesis 1c about the relationship between IILs and diverse forms of knowledge sourcing, is only partly supported. We find that IILs have a significantly negative impact on Internal network ($\beta = -0.19$, $p < 1\%$), but no particular effect on either form of external knowledge sourcing. Finally, being a LILs subsidiary does not seem to affect the forms of knowledge sourcing examined. The results provide partial support for Hypotheses 1a and 1c, but do not support Hypothesis 1b.

--- Table 2 goes about here ---

Hypothesis 2 refers to the impact of the host location's endowments on the three forms of knowledge sourcing. The coefficients of the impact of local endowments on host country knowledge sourcing is significant and positive ($\beta = 0.25$, $p < 1\%$), and for the impact on home country knowledge sourcing is also significant and positive ($\beta = 0.31$, $p < 1\%$). Finally, we find a negative and significant impact of host location's

[7] For simplicity reasons, we make use of the Greek letter 'β' in order to report all the estimated coefficients of the regression results, while 'p' denotes the level of significance.

endowments on internal knowledge sourcing (β = -0.19, $p < 1\%$). These results generally support Hypothesis 2.

Finally, for Hypotheses 3a and 3b and the effect of IPR distance on the multiple forms of knowledge sourcing, we find a significantly positive relationship between our explanatory variable and the level of internal knowledge sourcing (β = 0.67, $p < 10\%$) and a significantly negative relationship between IPR distance and the level of external host knowledge sourcing (β = -0.53, $p < 5\%$). We did not detect a significant effect on the relationship between IPR distance and external home knowledge sourcing. Our findings generally support Hypothesis 3b.

Among the control variables, we find that a greenfield site and a production subsidiary, being geographically distant to the home location, and having a UK headquarters, all have a negative impact on external home knowledge sourcing. At the same time, a large cultural distance between the home and host location has a positive effect on external home knowledge sourcing.

5. Discussion

5.1. Discussion of research findings

Hypothesis 1a predicted that SL subsidiaries will prefer to engage in internal knowledge sourcing. However, our findings indicate the opposite (i.e. a preference for external knowledge sourcing). This might be explained by the fact that, over time, this type of R&D subsidiary is likely to develop its own capabilities and knowledge and evolve to become a different type of unit (Birkinshaw & Hood, 1998), which potentially might weaken its ties with the intra-MNE network. In other words, over time, the organizational and knowledge processing structures of SL subsidiaries are likely to change, resulting in a greater focus on external rather than internal knowledge sourcing.

Our findings do not support Hypothesis 1b about the relationship between LIL subsidiaries and knowledge sourcing. We know that LILs are mandated to coordinate closely with various other functions in their local environment in order to develop or enhance products according to local needs and scope with the result that this type of subsidiary functioning falls within SLs and IILs subsidiaries. A possible explanation for this lack of support for Hypothesis 1b is that LIL subsidiaries undertake a wide range of research or production/adaptation work when compared to the narrower mandate of the other two types of R&D subsidiaries. Hence, this diversity might have affected the survey responses and produced a large variation in the responses to the questions on knowledge sourcing.

We argue also that IIL subsidiaries are unlikely to source knowledge from the internal MNE network. IIL subsidiaries are less likely to develop synergies with other affiliated units since their objective is to cultivate current contacts in the host economy, and to collaborate with the domestic scientific community, a more fruitful strategy for knowledge generation. In line with the extant literature, which suggests that IIL subsidiaries usually seek knowledge from new and creative sources that are predominant in the external environment (Manolopoulos, Dimitratos, & Sapouna, 2011), we predicted a positive relationship between IIL subsidiaries and external host knowledge sourcing. Although our empirical results support the negative relationship between IILs and internal knowledge sourcing, we did not find support for a positive relationship between IILs and host knowledge sourcing. A possible explanation for this result is that the extent to which an IIL subsidiary will source knowledge from the external host environment is affected by other, equally important factors such the host country's institutional and regulatory regime (Zhao, 2006). Another potentially significant factor is the level of the subsidiary's technological competence. For example, less technological competence might promote more frequent and stronger ties with external actors compared to a more technologically competent subsidiary which would be more aware of the risk of potential spillover effects.

Another finding from our empirical analysis is that rich scientific endowment in the host location encourages knowledge sourcing from this location, but simultaneously discourages internal knowledge sourcing. Given the tacit and context dependent nature of the technological knowledge required for new product development, the only way to channel the scientific resources available in the host environment is through interaction with the actors in that environment. To exploit this channel of knowledge requires more than an arm's length relationship. The negative relationship between the local environment's scientific endowments and intra-MNE knowledge sourcing, confirms our initial prediction that subsidiaries that tap into the knowledge in the host location are probably complementing their internal knowledge with an equally important amount of external knowledge. Finally, and contrary to our expectations, the richness of the host location's endowments has a positive rather than a negative impact on home location knowledge sourcing. A possible explanation for this is that our sample firms originate from technologically and economically developed countries. Hence, in many cases, the host and home locations' endowments will be interrelated.

Finally, we find that stronger IPR protection in the host location (compared to the home location) reduces the subsidiary's knowledge sourcing in the host location. On the other hand, strong IPR encourages the use of knowledge in intra-MNE networks. This finding needs further investigation since countries with weak IPR regimes are likely to be those locations where there is availability of low cost scientific labour. Our empirical findings suggest that there is a distinction between technology transfer and home-base exploiting activities (which require strong IPR), and technology creation activities and home-base augmenting activities, where a weak IPR regime allows more knowledge spillovers and information leakages, possibly through staff mobility. Since most of the R&D subsidiaries included in our sample are technology-creating subsidiaries, our results may be a reflection of the nature of our sample.

5.2. Theoretical contribution and implications for managers and policy makers

We set out to provide a more comprehensive view of the potential utilization of the various sources of knowledge that are available to international R&D subsidiaries. Previous research focuses on knowledge source dichotomies (internal vs external, or external home vs external host). Based on recent multinational patenting trends and advances in the technology management literature, we extend work on knowledge sourcing by the international R&D subsidiary and propose a more holistic framework that includes three distinct knowledge sources (external host, external home, and internal) which international R&D subsidiaries can draw upon simultaneously. This framework could be exploited in future studies to understand and evaluate how the modern MNE manages synergistic knowledge at the global level. We contribute also by assessing both internal- (R&D mandate) and external-related antecedents (local scientific richness and IPR distance), to understand the type of knowledge sourcing that will be favoured by the R&D subsidiary and in what circumstances (i.e. what factors influence this choice). Our framework is based on a synthesis of existing work on this topic, and could be used to evaluate when it is more advantageous for an MNE to leverage its internal knowledge versus exploiting the location specific characteristics of the home and host locations

The practical implications of our study suggest that R&D managers should focus on establishing several socialization mechanisms, that is, frequent contact among the different R&D units through long-term job rotations and short-term visits (Mendez, 2003). The more that the MNEs' units transfer and share ideas and targets, the more likely that their employees will exchange valuable resources and complementary knowledge (Björkman, Barner-Rasmussen, & Li, 2004). Firms' use of ICT and advanced knowledge management practices has eased access to the technologies available in the MNE by its international R&D labs. ICT use has also encouraged the formation of virtual teams. These variables were not captured by our survey, but have been shown to be important for fostering intra-MNE collaboration (Forman & van Zeebroeck, 2012).

In addition, subsidiary managers should be aware that strong IPR does not necessarily guarantee better linkages and greater synergies with external actors. Our results indicate that weak IPR in the host location can facilitate knowledge sourcing from the host environment. Therefore, managers should take account not only of the level of institutional protection in a given region/country but also factors such as the type of firms in a specific cluster, the type of R&D subsidiary, and the quality of the knowledge that is available in the local environment.

Our findings should be of interest to policy makers keen to attract technology-intensive FDI through tax incentives - often aimed at improving domestic technological capabilities through local interactions. Our results indicate that increased technology linkages with local firms and institutions requires more investment in the scientific technology base. Also, governmental institutions and policy making related to intellectual protection in a region or country should consider that a stronger IPR protection regime in the host location (compared to the international R&D subsidiary's home location) may not promote greater interaction with the host location's actors and organizations. Contrary to the conventional wisdom, firms are equally interested in knowledge spillover opportunities or forms of 'informal knowledge collaboration'. Policy makers must take account of the country of origin of the firms that traditionally make technology investments in their region since both home and host institutional environments seem to influence the level of the subsidiary's knowledge sourcing.

5.3. Research limitations and areas for future research

Our study has several limitations. First, we use cross-sectional rather than panel data and so cannot control completely for the heterogeneous abilities of parent-subsidiary pairs, or for the evolution of knowledge sourcing over time. Second, we lack detailed cost and value data which would allow us to distinguish between particular strategies and average outcomes captured in our regression analysis. However, given the growing interest in the geographic distribution of R&D and firm strategies to realize greater value from such investments, these limitations suggest directions for future research. We hope that our proposed framework and methodology prove useful in this context. Further research could explore the performance implications (innovative, organizational, and financial) of the three sources of knowledge (external home, external host, and internal) and the potential moderating effects, such as how the institutional and resource-related factors in the national system of innovation might moderate the knowledge sourcing and subsidiary/MNE performance relationship.

6. Conclusion

The novel contribution of our paper is the comprehensive consideration given to all three forms of knowledge sourcing (external home, external host, and internal) which a subsidiary might engage in, and which also takes account of factors that might be associated with higher or lower levels of that knowledge sourcing. Drawing on the existing literature on subsidiary knowledge sourcing, and extending the multiple embeddedness perspective, we have proposed a comprehensive conceptual research framework to examine the extent of local and global knowledge sourcing by R&D subsidiaries. We argue and show that the factors associated with each type of knowledge sourcing differ. The utilization of each source of knowledge is contingent upon the subsidiary's R&D mandate, the research endowments in the host location and the IPR distance between the host and home locations. Although our data do not take account of two important locations for R&D generation (i.e. India and China), our study provides evidence on and contributes to our understanding of how international R&D subsidiaries source knowledge from all the available networks.

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TABLES

Table 1. Pair-wise correlations

		1	2	3	4	5	6	7	8	9	10	11	12
1	External Home	1.00											
2	External Host	0.33	1.00										
3	Internal	-0.21	-0.27	1.00									
4	SLs	-0.08	-0.32	0.01	1.00								
5	LILs	0.00	-0.21	0.24	0.18	1.00							
6	IILs	0.09	0.26	-0.43	-0.29	-0.42	1.00						
7	Endowment	0.18	0.41	-0.33	-0.19	-0.22	0.30	1.00					
8	IPR distance	0.23	0.06	-0.12	-0.14	-0.10	0.14	0.09	1.00				
9	Greenfield	0.01	0.09	-0.11	-0.15	-0.17	0.20	0.17	0.19	1.00			
10	Production subsidiary	-0.23	-0.17	0.29	0.13	0.15	-0.31	-0.22	-0.06	-0.03	1.00		
11	Geographic distance	-0.30	-0.13	0.13	0.08	0.12	-0.15	-0.14	-0.04	0.05	0.09	1.00	
12	Cultural distance	0.31	0.00	0.02	-0.23	-0.01	-0.02	0.07	0.35	0.19	-0.16	-0.09	1.00
	Mean	2.13	1.79	1.86	1.78	2.05	2.11	1.73	-0.03	0.68	0.69	8.55	0.43
	Std. Dev.	0.49	0.34	0.46	0.76	0.75	0.89	0.54	0.94	0.47	0.47	0.81	0.50

Coefficients with values greater than |0.15| are significant at the 10% level of significance.

Table 2. Seemingly Unrelated Regression Equations (SURE)

		External Network Home	External Network Host	Internal Network
H1a	SLs	0.13 (0.06)**	-0.10 (0.04)**	-0.13 (0.06)**
H1b	LILs	0.07 (0.07)	0.00 (0.04)	0.02 (0.07)
H1c	IILs	0.07 (0.06)	0.02 (0.04)	-0.19 (0.06)***
H2	Endowment	0.31 (0.08)***	0.25 (0.05)***	-0.20 (0.08)**
H3a-b	IPR distance	0.03 (0.39)	-0.53 (0.26)**	0.67 (0.38)*
	Greenfield	-0.24 (0.09)**	-0.01 (0.06)	-0.01 (0.09)
	Production subsidiary	-0.20 (0.10)**	-0.08 (0.06)	0.12 (0.10)
	Geographic distance	-0.13 (0.06)**	0.04 (0.04)	-0.01 (0.06)
	Cultural distance	0.43 (0.12)***	0.05 (0.08)	-0.01 (0.12)
	US	0.04 (0.22)	-0.23 (0.15)	0.35 (0.22)
	UK	-0.38 (0.17)**	0.05 (0.11)	0.03 (0.17)
	CP	-0.10 (0.11)	0.12 (0.08)	-0.02 (0.11)
	EC	-0.11 (0.13)	-0.01 (0.09)	0.17 (0.13)
	PH	-0.03 (0.15)	-0.07 (0.10)	0.09 (0.15)
	Constant	2.37 (0.67)***	1.76 (0.46)***	1.96 (0.67)***
	Chi2	77.13***	61.02***	50.00***
	R-squared	0.46	0.40	0.35

Levels of Significance: *** $p < 1\%$ ** $p < 5\%$ * $p < 10\%$ (S.E. in parentheses).