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The multiple embeddedness of MNEs? foreign R&D subsidiaries in external home, external host and internal networks

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Abstract

We examine two implications of the conjecture that the R&D subsidiary of an MNE can potentially embed itself in three different networks viz. the science base of the home country, the science base of the host country, and/or the internal knowledge network of sister subsidiaries and parent MNE. First, we explore the type of relationship (complementary or substitutive) that exists between the three networks. Second, we develop a set of hypotheses about the factors that are associated with each kind of embeddedness. We test these conjectures on data obtained from internationally located MNE R&D subsidiaries. We find that home and host country external embeddedness, as well as embeddedness among

home and internal networks are complementary. On the other hand a substitutive relationship is observed between internal embeddedness and external host embeddedness. Additionally we find that the factors associated with each kind of subsidiary embeddedness are different.

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The multiple embeddedness of MNEs' foreign R&D subsidiaries in external home, external host and internal networks

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ABSTRACT

We examine two implications of the conjecture that the R&D subsidiary of an MNE can potentially embed itself in three different networks viz. the science base of the home country, the science base of the host country, and/or the internal knowledge network of sister subsidiaries and parent MNE. First, we explore the type of relationship (complementary or substitutive) that exists between the three networks. Second, we develop a set of hypotheses about the factors that are associated with each kind of embeddedness. We test these conjectures on data obtained from internationally located MNE R&D subsidiaries. We find that home and host country external embeddedness, as well as embeddedness among home and internal networks are complementary. On the other hand a substitutive relationship is observed between internal embeddedness and external host embeddedness. Additionally we find that the factors associated with each kind of subsidiary embeddedness are different.

Keywords: Subsidiary Embeddedness; Parent Subsidiary Links; R&D Mandate; Subsidiary Roles; Locational Endowments

1. Introduction

The external embeddedness of the Research and Development (R&D) subsidiaries of Multinational Enterprises (MNEs) in their host economies, is seen as an important element of the knowledge management strategy of the MNE by a large and emerging literature on international business (Cantwell, 2009). The need for external linkages in the host country typically arises from one of three motives - because the subsidiary may want to tap into the science base of the host country (e.g. investments around famous universities) or into a cluster of suppliers of intermediate products (e.g. semi-conductor fabrication in Taiwan) or to tap into inter-firm peer networks that are concentrated in particular countries and geographies (e.g. Silicon Valley, Cambridge). Furthermore, the external embeddedness of technology creating activities in a host economy (which may co-exist with considerable degrees of autonomy) is often counterpoised with a strong internal embeddedness of the subsidiary within the MNE's subsidiary network. The internal embeddedness serves to exchange technological knowledge and information from sister affiliates and parents to the subsidiary and Lahiri (2010) shows such intra-MNE ties play an integrative role in fostering knowledge management within the MNE and improve the overall quality of geographically dispersed R&D.

This emphasis on the centrifugal (or spread) forces in R&D management is contested by the technology management literature which has long argued that centralisation of R&D activity at home locations (or centripetal forces) dominate in the geographical organisation of R&D and will tend to favour home based networks of knowledge more amenable to control and perhaps also more trusted by headquarters (HQ) (Patel, 2010; Patel and Pavitt, 1991; Verspagen and Schoenmakers, 2004). Criscuolo (2009)

shows that the citations to patents from the MNE's home country remain very important and argues that embeddedness within the home country's national system of innovation (NSI) is as important as embeddedness within host environments and may be the source of a different type of spillover due to the internationalisation of R&D that is little studied – knowledge spillovers to the home economy rather than the host economy.

This view about home country embeddedness is also confirmed by several studies in the economic geography tradition (reviewed in Werker and Athreye, 2004) which have questioned whether regional advantages influence the innovative activity of firms by encouraging host embeddedness. While small firms appear to benefit greatly from specific regional advantages, large firms which depend on international, national and regional resources in order to carry out their technology creating activities are not always influenced by regional factors and features (Doloreux, 2004; Karlsson and Olsson, 1998). This set of results gives credence to the centripetal view where the organising abilities and technological advantages of the home country dominate the innovative performance of large firms.

The extant literature in international business and technology management on the embeddedness of R&D subsidiaries is one-sided in that studies in international management focus on external host and internal embeddedness relationships alone (Almeida and Phene, 2004; Blanc and Sierra, 1999; Lee *et al.*, 2001; Sumelius and Sarala, 2008; Yamin and Andersson, 2011), while those in the technology management tradition consider mainly the external home and external host embeddedness roles (Criscuolo, 2009; Criscuolo *et al.*, 2005; Le Bas and Sierra, 2002). Both represent partial views of the world and so are potentially misleading.

In this paper we develop the implications of the conjecture that an R&D subsidiary can draw upon host and home country external network, as well as its internal knowledge context when searching for sources of technological knowledge and the extent to which it is embedded in the three networks is a strategic choice made by the HQ. Two questions then arise: First, how can we conceive of the relationships between the three networks - are they complementary or substitutive? Second, what are the unique predictors for each type of embeddedness? The answers to both questions are important in order to assess how the MNE exercises leverage or arbitrage in locating their R&D activities based on location specific characteristics of the home and host locations, as well as the knowledge resources available in other parts of the MNE's network of subsidiaries.

The remainder of the paper is organised in the following way: Section 2 develops a framework for thinking about the relationships between the three types of embeddedness and draws upon the extant literature to derive propositions about the factors that might predict more of one type of embeddedness over the other. We test these conjectures using survey data on R&D subsidiaries located in 14 different international locations and these data are described more fully in Section 3. Section 4 outlines the methodology employed in the paper. One implication of the conjecture that the MNE can use one or all networks is that the decision to embed itself in host, home or the internal network is a joint decision and should be modelled as such. In this we depart from single equation representations of trade-offs between home and host embeddedness, home and internal embeddedness or host and internal embeddedness. Sections 5 and 6 of the paper present and discuss our main findings respectively, while in section 7 we conclude by highlighting all possible implications and limitations of the study.

2. Literature review and hypotheses development

2.1 Notions of embeddedness and their application to the MNE

The idea of firm embeddedness originates in the literatures in economic sociology and economic geography and is associated with slightly different meanings in each case. In the economic sociology literature, Granovetter (1985) pioneered the view that economic relations between firms and their environment are mediated by social networks and relations between them. He also argued that the strength of these networks and relationships shaped information flows between those agents – in particular the counter intuitive idea that weak ties (infrequent interaction) were more important than strong ties (more frequent interaction) in several situations.

In the economic geography literature, the concept of embeddedness is crucial to the idea of 'the untraded competencies of a region' (Boschma and Martin, 2010; Maskell and Malmberg, 1999; Storper, 1997) that confer advantages to firms locating in those regions. Here embeddedness refers to factors embedded in a region, such as the social culture, the specific politics, the development of technology creating institutions with their linkages and other aspects of history and endowments which may confer more lasting competitive or technological advantage. Thus, unlike the sociology literature where embeddedness arises as a consequence of interpersonal social interactions the geography literature's view of embeddedness is more predicated on a proximity based view. Since technology is assumed to have a large tacit component which benefits from frequency of interaction and sharing of abstract concepts, the economic geography view of embeddedness has become important to discussions of technology transfer from the broader environment to the firm.

In the context of the MNE, two notions of embeddedness, internal and external, have been considered important. Internal embeddedness refers to the MNE subsidiary's

position within the federated network of affiliate subsidiaries and the parent company and the frequency of its interaction with sister and parent units. Similarly, Andersson and Forsgren (1996) define the subsidiary's degree of external embeddedness as a measure of relevant direct and indirect relationships the subsidiary has developed with suppliers, customers etc, as well as by taking into consideration the aspects of the particular transactions with them echoing the ties' view of embeddedness emphasised in the sociology literature. Almeida and Phene (2004) who first emphasised the importance of this distinction for technology creating activities however, lean towards a more economic geography interpretation of proximity. They argued that an MNE firm's decision on what type of R&D unit will be established and where may be influenced by the level and density of network embeddedness between the unit, the parent company, the other affiliates and the external actors (firms and institutions) of the host location. The depth of embeddedness is usually measured by the frequency of interaction - a concept that comes from the sociological literature on ties.

As we noted in the introduction, MNEs' subsidiaries are actually situated in three interrelated networks viz. external home, external host and internal network. Although the innovative activities of the leading MNEs have followed a more globalised route throughout the years (Cantwell, 1995), it is also known that MNEs predominantly internationalize their R&D activities and accordingly locate them in technological fields where they are strong at home (Les Bas and Sierra, 2002; Patel and Vega, 1999). This fact underlies the common notion that innovative activities implemented in the home country confer huge competitive advantages for the MNE (Le Bas and Sierra, 2002).

In case of the MNE R&D subsidiary, the host location under which it operates can provide a network of resources and partners whose contribution (knowledge) is likely to complement the existing knowledge derived from the home location of the MNE. Evidence for this proposition comes mainly from the study of patent citation data drawn from European and US MNEs (Criscuolo et al 2005). Criscuolo (2009) argues that substituting home with host location's NSI carries significant drawbacks with immense negative aspects for the whole MNE (e.g. knowledge spillovers to competitors in the host location). D'Agostino and Santangelo (2012) show that R&D subsidiaries of OECD-based firms with a pure adaptation profile (and operating in the top six emerging economies of the world) tend to complement host R&D with home region knowledge creation. Thus, we may expect that the two external networks - home and host - will have a complementary relationship. Accordingly, we draw the following hypothesis:

H1a: External network of the home country and external network of the host country under which foreign R&D subsidiaries are embedded will have a complementary relationship in the sense that more of one type of embeddedness will give rise to more of the other type of embeddedness.

The relationship between internal and external network embeddedness on the other hand appears to be a bit more ambiguous. Evidence from Small and Medium Enterprises (SMEs) shows that internal and external resources form a complementary relationship that enhance the firm's absorptive capacity as regards the external knowledge acquisition (Hervas-Oliver and Albors-Garrigos, 2009). However, Blanc and Sierra (1999) argue that since an MNE R&D subsidiary apart from adapting itself to the host location under which it operates, also aims to benefit from possible

knowledge spillovers arising from its internal network, its internal corporate embeddedness and external embeddedness may act as substitutes or complements. Similarly, Gammelgaard and Pedersen (2010) conducting a survey on external and internal knowledge sourcing of subsidiaries find a non-linear relationship between the two. More specifically, the relationship between the two is complementary but is transformed to a substitutive one when the subsidiary's resource constraints become predictable and binding. These resource constraints in turn lead the R&D subsidiary to a more tied relationship with only one of the two networks. Yamin and Andersson (2011) investigating the role of internal embeddedness on subsidiary's importance within the MNE indicate that when internal embeddedness is made to interact with external embeddedness, external embeddedness no longer has a positive explanatory role in explaining the subsidiary's importance suggesting again that the relationship between internal embeddedness and external host embeddedness is likely to be substitutive.

We follow Gammelgaard and Pedersen, (2010) and conjecture that the internal embeddedness of the subsidiary is a choice variable for the parent firm, which in turn will also decide how the subsidiary utilizes the home country networks. This control exercised by the parent suggests that internal and external home networks may be complements and the position in both is fully controlled by the parent. Activities that increase external host location embeddedness are however controlled by the subsidiary and this may involve trade-offs about how highly the subsidiary can be integrated in the internal network of the MNE due to the large coordination costs that may arise from two managements (parent and subsidiary) having to synchronize their goals and activities. Accordingly, we suggest the following hypotheses:

H1b: External network of the home country and internal network under which foreign R&D subsidiaries are embedded will have a complementary relationship in the sense that more of one type of embeddedness will give rise to more of the other type of embeddedness.

H1c: External network of the host country and internal network under which foreign R&D subsidiaries are embedded will have a substitutive relationship in the sense that more of one type of embeddedness will result to less of the other type of embeddedness.

2.2. Influences on the type of embeddedness

2.2.1. The R&D Mandate

An important distinction is that of R&D subsidiaries whose technological activities are home-base augmenting (HBA) and those whose technological activities are home-base exploiting (HBE) (Cantwell and Mudambi, 2005; Kuemmerle, 1997)[1]. Studies have shown that the two types of R&D subsidiary tend to behave differently vis-à-vis their external linkages. HBA labs develop strong ties with research institutions and universities, while HBE subsidiaries increase the degree of liaison with their local customers (Ambos, 2005). In our study we will adopt the classification first used by Hood and Young (1982) and Pearce (1994). These studies categorize the MNEs' foreign R&D labs to three distinct roles. The first type of R&D is that conducted in Support Laboratories (SLs), whose main role is to adapt existing products and processes. The second type is the Locally Integrated Laboratories (LILs). This type of

[1] A large number of studies on the internationalization of R&D have focused on defining, explaining and producing R&D typologies in order to further explain recent trends, host location characteristics and managerial implications on why, where and how MNEs' R&D activities go international. (Gassmann and von Zedwitz, 1999; Håkanson and Nobel, 1993; Le Bas and Sierra, 2002; Nobel and Birkinshaw, 1998; Von Zedwitz and Gassmann, 2002). We focus on the simplest of these typologies viz. HBE and HBA activities.

laboratory is closely coordinated with various other functions of the subsidiary's local environment in order to develop or enhance products according to local needs and scope. The third type is the Internationally Interdependent Laboratories (IILs). This type of lab has no systematic connection with the MNE's production units, since it works with other interdependent networks from all over the globe targeting new scientific effort in order to create new product and process patterns. Thus, SLs and LILs are oriented toward adaptation of existing products and distribution of them in the host market, while IILs are more independent research units where novel research is conducted.

Andersson, Forsgren, and Holm (2002) show that there is a complementary relationship between the (host) external network of the affiliate (in terms of technical embeddedness) and its R&D specific role (as a source of knowledge for other sister units), while Andersson (2003) shows that external technical embeddedness is positively related to a subsidiary specific role within the MNE[2]. Thus, there is a strong suggestion in these studies that the external (host) network orientation of the R&D subsidiary is associated with the mandate of R&D subsidiaries.

On the other hand, we also know from the technology management and economic geography literatures that the home country embeddedness of firms is important for their innovation. Criscuolo (2009) argues that in order for the MNE to harvest maximum gains from the R&D activity that takes place abroad, there should be no doubt that the MNE's R&D function is well-tied into the parent country's network. Furthermore, Gertler, Wolfe, and Garkut (2000), based on Canadian data from the Ontario region, show that indigenous firms were more likely to perform innovative

[2] Both these studies are based on data for Swedish MNEs which are much more internationalized in their R&D activities due to the relative smallness of the country (Patel 2010).

activities locally and were more embedded in the local economy than their multinational counterparts, as they exhibited higher R&D intensity, had a larger proportion of scientific, technical and managerial employees, adopted innovative inter-firm practices more extensively, and were more likely to source innovative ideas from local customers. The multinational establishments, in contrast, tended to exhibit lower R&D intensity, were more reliant on their in-house marketing units, and continued to rely on their parent companies (internal network) as a primary source for innovative ideas. The finding of the dependence of MNE subsidiaries on their parent for innovation and their lower R&D intensity is also echoed by studies on knowledge spillovers (Driffield and Love, 2007; Veugelers and Cassiman, 2004). Williams and Nones (2009) distinguish the embeddedness behaviour of basic research units and service subsidiaries and show that basic research units are more embedded in the internal network of the MNE and more isolated from their external (host) network, while service subsidiaries are more prone to extend their communication with local customers (i.e. external host network).

Thus, we conjecture that R&D labs with a more adaptive character (SLs and/or LILs) will tend to be more embedded within the host environment's external network, because the region specific information needed for adaptation is likely to be more readily available there. R&D labs with a more original research profile (IILs) will have a propensity to be engaged in the home external network as the tacit knowledge and people-specific elements of new technological research and strategic considerations are likely to tie them to sources of deeper network ties in the home country. Hence:

H2a: Foreign R&D subsidiaries acting as IILs will be embedded in the home (parent) country's external network.

H2b: Foreign R&D subsidiaries acting as SLs and LILs will be embedded in the host location's external network.

2.2.2. Environmental uncertainty

The public good nature of technological knowledge implies that knowledge spillovers, information leakage, macroeconomic instability and weak Intellectual Property Rights (IPR) protection impose substantial costs for the R&D subsidiary in foreign locations. Furthermore, their company HQ are not in a position to control for undesirable trade-offs. A strong IPR protection regime has been found to be a positive determinant of technology investment attractiveness (Kumar, 1996; Narula and Guimón, 2010; Saggi, 2002).

From the perspective of R&D subsidiaries, knowledge dissemination usually takes place through staff inter-firm mobility and frequent liaisons between the lab and its external network (Blomstrom and Kokko, 2003). Interestingly these factors can also play a useful role in deepening host embeddedness. Nonetheless, the existing literature does not provide a clear view on whether potential R&D leakage influences the extent to which a lab embeds itself in its external or internal environment, once the decision to be located in a country has been taken.

Zhao (2006) conjectures that MNEs which face such problems will tend to highly internalise their knowledge (tied more in their internal network) and practice careful task portioning in order to avoid any losses due to technological spillovers – and demonstrates this to be true in the case of China. Using case studies of Indian R&D units, Kumar and Puranam (2012) argue that firms may be able to reap valuable externalities of their embedded network by developing the adequate internal managerial techniques in order to raise awareness of IP and thus tackle any

knowledge spillover and R&D leakage problems. Accordingly, we expect that R&D units facing potential R&D leakage challenges will tend to further strengthen their ties with their internal network, while those ties will be more embedded in the host location if the potential for R&D outflow is to a certain extent limited.

Furthermore, host locations surrounded by high macroeconomic instability will force R&D subsidiaries to extend their ties with the home (parent) network of the MNE. Thus:

H3a: Foreign R&D subsidiaries operating in a host environment embraced by high macroeconomic instability will be embedded in the home (parent) country's external network.

H3b: Foreign R&D subsidiaries operating in an environment which has a strong IPR protection regime will be embedded in the host country's external network, while R&D subsidiaries surrounded by a weak IPR protection regime will be embedded in the MNE's internal network.

2.2.3. Subsidiary autonomy

The degree of autonomy with which each subsidiary operates is a decision conventionally set by the HQ of the MNE. Prior literature in international business has explicitly researched the particular role of subsidiary autonomy and its impact on economic development and firm performance (de Jong and van Vo, 2010; Edwards, Ahmad, and Moss, 2002; Johnston and Menguc, 2007; Slangen and Hennart, 2008; Taggard and Hood, 1999). From the perspective of the questions explored in this paper, allowing subsidiaries independence may decrease some kinds of coordination costs especially in mature technologies and also be a more efficient way of searching for local partners for technology creation. The existing literature has investigated the

relationship between the degree of autonomy of R&D subsidiaries and the extent of their internal and external host embeddedness. Accordingly, Andersson and Forsgren (1996) have identified a positive relationship between the degree of external (host) embeddedness and the level of autonomy allowed to the subsidiary by the HQ indicating that subsidiaries acting as more autonomous and decentralized entities will rely more on their surrounded external environment. On the other hand, a negative association among internal embeddedness and the degree of subsidiaries' autonomy has been observed in other studies (Andersson and Forsgren, 1996; Birkinshaw and Morrison, 1995). Accordingly, we conjecture our hypothesis as follows:

H4: Foreign R&D subsidiaries acting as more autonomous (i.e. decentralised) units will be embedded in the host location's external network, while R&D subsidiaries acting as less autonomous (i.e. centralised) units will be embedded in the MNE's internal network.

2.2.4. Endowment's technological and scientific richness

The hypotheses developed above stress costs of doing R&D that are common to all locations since they depend mainly on the transaction costs of undertaking dispersed technological activities that stem from tacitness and appropriability of knowledge. These costs must be evaluated against the benefits of location. Indeed, one of the most studied themes in international R&D investment is the location specific factors of the host country stemming from the local endowment of national resources and institutions. Among location-specific endowments, the role of domestic stock of knowledge and the existence of large labour pools in science and technology are stressed in a large number of studies on technology based FDI (Cantwell and Mudambi, 2000; Cantwell and Piscitello, 2002; Dachs and Pyka, 2010; Demirbag and

Glaister, 2010; Groh and von Liechtenstein, 2009; Lewin, Massini, and Peeters, 2009; Narula and Guimón, 2010; Sachwald, 2008; Saggi, 2002; Varsakelis, 2001; Varsakelis, 2006). In general it is argued that locations surrounded by technological excellence, scientific richness, qualified labour pools and business friendly institutions, all together forming a strong NSI, are more likely to attract greater volumes of MNEs. Accordingly, the incorporated R&D labs will tend to establish strong network ties with the external host environment in order to get reap of the host location's scientific advantage. Hence, we assume that:

H5: Foreign R&D subsidiaries operating in host locations with strong technological endowments will be embedded in the host country's external network.

3. Data and variables

3.1. Profile of the sample

The data used in our analysis are drawn from a survey of 133 overseas subsidiary R&D centres undertaken in 1989[3]. The survey included the MNE's larger non-parent R&D unit whose role was to support local marketing and/or engineering activities, or to be capable of advanced research by contributing in a globally integrated research program. The detailed nature of questions asked in this survey and their responses at a time when R&D managers were not yet sensitised to the issue of network embeddedness make it a useful source of data on which to test our conjectures. The sampling frame consisted of the Fortune 500 list published in 1986 when only 405 of

[3] Although our study's dataset may be perceived as quite dated, given the fact that over two decades have passed since the year this survey took place, recent evidence shows that other empirical studies focused on innovative activities of MNEs have also incorporated relatively old data in their analyses. Some examples are the studies by Un and Cuervo-Cazurra (2008), using data from the period 1991-1994, Nell and Andersson (2012), using data collected within the period 1990-1994, and Mudambi *et al*. (2007), incorporating data corresponding to the year 1995.

the 500 units had established R&D facilities abroad, and thus the feasible sample was automatically reduced to almost 405 industrial companies. A questionnaire was sent via mail to the existing population of foreign R&D units[4]. In total, 135 questionnaires were returned. Of these, two were considered as unusable[5] truncating our final sample to 133 observations – a response rate of almost 32.8 per cent.

In order to better describe the global distribution of R&D units we incorporate a cross-tabulation table (Table 1) which presents the host countries in which MNEs operate R&D laboratories. From the table it comes clear that European MNEs tend to operate overseas R&D laboratories mainly in the US, while there is evidence that US and UK firms prefer to allocate their R&D units in UK and US territories respectively. As concerns our sample's distribution, it can be rather assumed that this is quite representative as regards the already known global research activity of MNEs.

--- Table 1 goes about here ---

Patel and Pavitt (1991) through their renowned research study on large firms and production of world's technology identify that the US accounts for almost the half of the global activity, while Japan and the UK follow. As it was expected, R&D subsidiaries based in the US, the UK and Japan account for the 71.4 per cent of the total sample, a result quite expected taking into consideration the increased internationalization strategy of MNEs toward countries surrounded by research and

[4] The first questionnaires were sent out in October 1988 and the last ones in June 1989, while the first completed questionnaire was received back in November 1988 and the last one in August 1989. The survey questionnaire is available from the authors upon request.

[5] By mistake these two R&D subsidiaries were perceived to operate away from their parent location. Apparently, when the questionnaires were received it was reported that these are domestic R&D units operating close to the HQs of the parent company. Hence, we excluded these two observations from our final sample.

technological excellence. On the other hand, as can be seen from Table 1 many of the new R&D locations, such as Israel, Ireland, India and China, are not covered in this survey. However, this may not be a major drawback. Dunning and Lundan (2007) estimate that the number of locations from which international R&D is drawn remains small despite the increased internationalisation of R&D and, based on patent data Patel (2010) also shows that the US and Europe continue to be the main locations for international R&D - these locations are very well covered in our data.

Although our study is based on relatively aged data, the geographic distribution of MNEs has not yet changed dramatically. Although emerging economies have now entered more than ever before into the game of internationalization, the assumption for non-globalization still holds. Taking into consideration the above facts, it can be supported that our data are still considered representative of today's global trends, since almost all the major countries of the global production map are reported in our sample. As regards the industry division of the sample, Table 2 reports that about 75 per cent of it consists of R&D subsidiaries in pharmaceuticals, electronics and chemicals and petroleum sectors – which are among the most internationalised sectors in R&D.

--- Table 2 goes about here ---

3.2. Controlling for non-response bias

In order to control for possible non-response bias in our sample we proceed to two different methods. First, we compare the number of respondents (N = 133) to that of the original population (N = 405) for all the examined geographical locations. Looking at Table 3 it can be derived that almost all the foreign locations where R&D subsidiaries operate are well represented considering our received questionnaires,

except for Canada, France and rest of the world countries, which are somehow underrepresented compared to our initial population.

--- Table 3 goes about here ---

Second, as concerns our final sample, and since some questionnaires were collected after respondents received a second notice (reminder), we are aware of a possible non-response bias that may negatively affect our sample's explanatory power. More precisely, from a total of 133 questionnaires, 99 responses were collected in first order and the rest 34 right after our reminder. Accordingly, an investigation of non-response bias was conducted by comparing responses which were collected under first and second attempt (Armstrong and Overton, 1977). By performing a t-test on subsidiaries' age and size characteristics we find no statistically significant difference ($p < 0.05$) between questionnaires belonging to those units replied before and after our reminder.

3.3. Variables created

The subsidiary specific variables used in this study are drawn from the survey's questionnaire, but many of the location specific characteristics are drawn from well known secondary data sources. Thus, the two proximity-related variables were taken from the CEPII (Institute for Research on the International Economy) database, while for the IPR index we use the Park Index. Also, the unemployment rate is obtained from the International Labour Organisation, while the inflation rate and GDP per capita are obtained from the WDI (World Bank) database.

3.3.1. Dependent Variables

Constructing measures of external and internal network embeddedness

The embeddedness of a subsidiary is measured either through the density of its relationships with different actors (as in Ambos, 2005) or in terms of the subsidiary's dependence upon particular relationships in its external environment (as in Andersson and Forsgren, 2000). Our questionnaire incorporates the following questions in regard to the degree of cooperation between the examined host R&D unit and the collaboration with the external environment in both subsidiary's home country and the examined host location, as well as with the internal environment under which the subsidiary operates.

External Home: This variable is constructed according to the survey's following 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? The answers to this question have a categorical-likert operationalization, ranging from 1 (no contacts reported) to 3 (regular contacts reported). We assume the higher the frequency of contact the more dependent is the subsidiary on those inputs. In order to create the variable *External Home* we use the mean score from responses to the above three questions as a measure of external embeddedness of the subsidiary in its parent/home country networks. The Cronbach's alpha value for this construct is 0.65.

External Host: The survey questionnaire also elicits the subsidiary's response to the following questions: 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 answers to all the above questions also have a categorical-likert formation, based on the frequency of interaction, and range from 1 (never) to 3 (regularly). Again we assume the higher the frequency of contact the more dependent is the subsidiary on those inputs. In order to measure the degree of external embeddedness in the host country (*External Host*) we take the mean score of a subsidiary's response over the above questions and we construct a measure of external embeddedness in the host country. Accordingly, the Cronbach's alpha value for this construct is 0.60.

Internal: Apart from the two previous forms of external embeddedness, the survey questionnaire provides valuable information in regard to the degree of internal embeddedness of the R&D subsidiary. The questions used in order to construct this variable are the following: What are the most likely sources of project ideas initiated in this unit? i) suggested by parent ii) suggested by sister affiliates iii) feedback from local production units iv) feedback foreign production units v) feedback from local marketing units vi) feedback from foreign marketing units vii) feedback from local sales channels viii) feedback from foreign sales channels. The answers to all the aforementioned eight questions are also in a categorical-likert formation, based on the frequency of interaction, and range from 1 (never) to 3 (regularly). The mean score of the above eight questions was taken in order to construct the aforementioned variable, while the Cronbach's alpha value is 0.71.

3.3.2. Independent Variables

The type of R&D Lab

The survey questionnaire allowed us to create a variable that could measure the type of R&D lab, according to the mandate allocated by the parent company. Thus, following the R&D subsidiary classification introduced by Hood and Young (1982)

and Pearce (1994), each unit was asked to classify its activities into the following categories:

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 program coordinated by the (parent) or other major laboratory?

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).

Environmental Uncertainty

IPR protection regime: This variable is constructed by the Intellectual Property Rights Protection Index (for years 1960-1990). The original scores of the IPR Protection Index (Park, 2008) range from 1 (weakest) to 5 (strongest).

Macroeconomic instability: The measurement of this particular scale variable is calculated by aggregating the level of unemployment (as a percentage of total labour force) and inflation, GDP deflator (annual percentage) in the host country. A range of research studies (Clausing and Dorobantu, 2005; Golden, 1993), especially in the field of economics, have used this sort of index in order to capture the misery level of the macroeconomic environment. In fact, an increasing level of this index indicates a poorer and more problematic macroeconomic climate for the country.

Autonomy

In order to measure the degree of R&D subsidiary's decentralization we use the following four survey-based questions. 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) technical assistance at the request of the R&D unit. The answers to this questions have a categorical-likert operationalization, ranging from 1 (regularly) to 3 (never). Accordingly, if the interaction with its affiliate and parent units is infrequent it is implied that the subsidiary is highly autonomous. The mean score of the above four questions was calculated in order to construct this variable, whose Cronbach's alpha value is 0.73.

Local endowment

In order to measure the degree of influence of the host environment on subsidiaries' decision to tap their activities into this particular location we use four questions from the survey. More analytically, the questions ask the respondents the following: 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 the research professionals. The answers to this question have a categorical-likert operationalization, ranging from 1 (irrelevant to decisions) to 3 (a major factor contributing to the decisions). The variable is calculated by taking the mean of the upper four questions, while the value of this construct's Cronbach's alpha is 0.72.

3.3.3. Control variables

Apart from the aforementioned determinants affecting the extent of R&D lab's embeddedness in its external and internal environment, other traditional parameters play also a distinctive role. Size and growth of the market play a key role for MNEs which seek to adapt their products according to the needs of the host environment. Large domestic markets are more likely to attract larger amounts of R&D investments of the HBE sort (Cantwell and Piscitello, 2002; Dachs and Pyka, 2010; Kumar, 1996; Kumar, 2001). Furthermore, other location-specific governance factors, such as the geographic (Gassler and Nones, 2008) and cultural proximity between the parent and the host country also influence the costs of R&D. Sharing a common language and being close are likely to be associated with similar norms in public science and an easier adaptability of the local workforce to the corporate culture of the MNE. Accordingly, we present a number of control variables which will be incorporated in the examined models.

Geographical Distance: This variable is calculated by taking the natural logarithm of geographical distance between the lab's parent country and its host location. The distances are calculated following the great circle formula, which uses latitudes and longitudes of the most important city (in terms of population) or of its official capital.

Cultural Proximity: This is a dummy variable taking the value 1 if a language is spoken by at least nine per cent of the population in both countries and value 0 otherwise.

GDP per capita: As an index of market potential (as in Fagerberg, 1987)

Production subsidiary: A survey-based dummy variable taking value 1 if the firm reported that it was an R&D facility which was associated with a production subsidiary. We include this variable to better capture technology augmentation, as suggested by Cantwell and Mudambi (2005).

LnYears: A survey-based scale variable measured by the natural logarithm of years of the R&D unit's operation in the host location. Ln(Year of survey-Year of R&D facility's incorporation).

LnSize: Again, a survey-based scale variable estimated by the natural logarithm of the R&D unit's employment at the most recent year of the R&D unit's operation.

Table 3 describes the variables created as well as their source and also presents some descriptive statistics for each of the variables.

Industry dummies: In order to control for possible industry effects on the degree of R&D subsidiaries' network embeddedness we incorporate industrial sector dummies. Accordingly, four industry dummies are constructed, while each one corresponds to a unique industrial division (Chemicals and Petroleum, Electronics, Pharmaceuticals and Miscellaneous industries).

Country dummies: We also make use of two country dummies for two of the most internationalised countries (in terms of R&D activities) of our sample (US and UK).

4. Econometric design

4.1. The baseline model: Seemingly unrelated regression equations (SURE)

As discussed, our dependent variables (*External Home*, *External Host* and *Internal*) are measures of the external (in the host and parent country) and internal network embeddedness respectively. Accordingly, in each equation, one form of embeddedness is taken as the dependent variable, while the rest two are incorporated as explanatory variables in order to examine the possible complementary and substitutive relationship that is hypothesised to exist among them. As regards the rest of the explanatory variables, these are of four types: variables that measure the mandate to the R&D unit denoted by the vector *M*, the level of environmental

(macroeconomic and institutional) uncertainty of the host location denoted by the vector *U*, host location's endowment richness (*E*) and the degree of autonomy (decentralisation) of the R&D subsidiaries (*A*). *C* is the vector of control variables which includes measures related to location-, subsidiary- and industry- specific characteristics.

A major issue in assessing the role of external host, external home and internal embeddedness is that they might be jointly determined and so modelling them as independent equations may not be correct. In reality, our model is based on three different linear equations. The differentiation in these three equations is first on the examined dependent variables (E_i^P, E_i^H and I_i), and second on the number and type of regressors used for each equation. From the formation of these three equations we expect that the error terms of the regression equations will be correlated. If such an issue holds, then SURE is defined as the most appropriate system for estimating the parameters of our model. Statistically speaking Cov (ε_i,ζ_i,), Cov (ε_i,η_i,) and Cov (ζ_i,η_i,) may not be zero. Thus we estimate the correlation of residuals deriving from each independent equation and based on the presence of correlation (which we expect due to the complementary and substitutive roles of external home, external host and internal embeddedness) we estimate the joint equation (1) below using the SURE method.

$$
\begin{aligned}
E_i^P &= \alpha + \beta_1 E_i^H + \beta_2 I_i + \beta_3 M_i + \beta_4 U_i + \beta_5 C_i + \varepsilon_i \\
E_i^H &= \gamma + \delta_1 E_i^P + \delta_2 I_i + \delta_3 M_i + \delta_4 U_i + \delta_5 A_i + \delta_6 E_i + \delta_7 C_i + \zeta_i \qquad (1) \\
I_i &= \lambda + \mu_1 E_i^P + \mu_2 E_i^H + \mu_3 U_i + \mu_4 A_i + \mu_5 C_i + \eta_i
\end{aligned}
$$

One advantage of the SURE method is that it enables us to include different sets of regressors, for E_i^P, E_i^H and I_i (Zellner, 1962). Accordingly we use those explanatory variables that are closest to the hypotheses we formulated. This particular method can be very efficient for our study, since different regressors are incorporated in each equation according to the already developed hypotheses in section 2. Consequently, equation (1) can be rewritten as follows in a more analytical way.

$$E_i^P = \alpha + \beta_1 E_i^H + \beta_2 I_i + \beta_3 IILs_i + \beta_4 Macro\_instability_i + \beta_5 C_i + \varepsilon_i$$

$$E_i^H = \gamma + \delta_1 E_i^P + \delta_2 I_i + \delta_3 SLs_i + \delta_4 LILs_i + \delta_5 IPR_i + \delta_6 A_i + \delta_7 E_i + \delta_8 C_i + \zeta_i \qquad (2)$$

$$I_i = \lambda + \mu_1 E_i^P + \mu_2 E_i^H + \mu_3 IPR_i + \mu_4 A_i + \mu_5 C_i + \eta_i$$

where the vector (C) includes all the following control variables:

Ln_Years, Ln_Size, Production_subsidiary, CP, EC. PH, US, UK, Ln_Geo_distance, Cultural_proximity, Ln_GDPPC.

4.2. Econometric issues

An important issue is the possible presence of multicollinearity between the variables and factors. Multicollinearity is initially identifiable through the correlation matrix, where variables can be highly, but imperfectly, correlated (Greene, 2003). If such a case holds, and although the regression analysis is processed normally, it is almost certain that severe statistical problems will come up and our model will turn out to be of inefficient quality. The correlation matrix (Table 4) indicates that possible presence of multicollinearity may hold among *GDP per capita* and *Macroeconomic instability* (ρ = 0.89). In order to further assess whether multicollinearity is an issue, we estimated the variance inflation factors (VIFs) for each coefficient in each examined model(s).

--- Table 4 goes about here ---

The VIFs scores (Table 4) in all the examined equations reported values no greater than the 'rule of thumb' of 10 (Hair *et al.*, 1998). Thus, multicollinearity is not an issue in any of the estimations.

5. Empirical findings

5.1. Descriptive statistics

Table 5 shows that, on average, the extent of home country embeddedness is higher than host country embeddedness in our sample of firms, though a slightly smaller number of firms seem to report the opposite. This may simply reflect the state of affairs in the internationalisation of R&D in the late eighties. The External host and internal embeddedness have similar magnitudes although internal embeddedness seems to be slightly higher than external host embeddedness. The dominant R&D mandate in our sample seems to be SLs. As regards the level of autonomy and local endowment, the descriptive statistics indicate that the sample of subsidiaries does not enjoy a great level of autonomy, but local endowments are perceived to be high.

--- Table 5 goes about here ---

The control variables suggest that 68 per cent of the sample consisted of production subsidiaries, while the average age of a R&D subsidiary in the sample was 26.2 years and the average R&D employment size was 154.3 people. Our location characteristics are drawn from well known secondary data sources but because we cover only 14 countries and not sub-regional units they exhibit limited variability.

5.2. Empirical results

Table A1 presents the correlation of residuals from each independent equation, while table A2 reports those OLS regressions. Table A1 shows that the residuals of the OLS equations are correlated and as such validates the use of a SURE methodology. When the OLS residuals of independent equations are correlated SURE estimates are statistically more reliable (Zellner, 1962).

Table 6 reports the results of estimating equation (2) using the SURE methodology. In equation (2) the majority of regressors are examined in relation to their expected impact on either home external, host external and internal embeddedness (as is derived from the hypotheses formulation). Firm, industry and country specific controls are incorporated in all equations. More specifically, natural logarithms of geographical distance between the host and the parent economies, a dummy variable indicating the cultural proximity among parent and host locations, natural logarithms of R&D unit's size and years of operation, industry and major country dummies, as well as a dummy variable indicating whether the R&D unit is also associated with a production subsidiary are included in the equations as control variables.

--- Table 6 goes about here ---

In Hypotheses 1a, 1b and 1c we tested whether a complementary or substitutive relationship exists among the three examined forms of network embeddedness. The results in Table 6 indicate a complementary relationship between external home and external host embeddedness, since external host and external home are found to have a positive and significant impact on external home and external host network respectively. Furthermore, internal network is found to have a positive and significant

correlation with the external home network, and a negative and significant correlation with the external host network. Thus, all our conjectures on the relationship between the three types of embeddedness are supported. It is also worth comparing these results to what we would have obtained if we modeled the choice of each type of embeddedness as independent of each other (Table A2). Accordingly, the OLS equation underestimates the extent of complementarity and also ignores the importance of internal networks in all the equations.

Hypotheses 2a and 2b test the impact of specific R&D mandate on external network embeddedness of host and home country. The estimates report that SLs have a significant positive impact on external embeddedness in the host country, while IILs are associated with greater home country embeddedness. These findings, which are related to the type of R&D lab, provide evidence that support-oriented labs rely on the external network of the host environment, while R&D units with a more novel and new product development research orientation tend to utilize (possibly) entrenched ties with the external network of the parent in its home country. The estimates in regard to the relationship between foreign R&D mandate and network embeddedness are in line with our expectations. As a result, hypotheses 2a and 2b are supported.

Regarding Hypothesis 3a, we find the coefficient on *macroeconomic instability* is positively and significantly associated with the external network in the home country indicating that insecure and unstable economic environments in host locations push R&D units to entrench ties with the home country. As regards Hypothesis 3b, the estimates indicate a negative and significant relationship between IPR protection regime and external host network, while no statistically significant result is found for its relationship with the MNE's internal network. These findings show that a strong IPR protection regime is indicated as a negative rather than a positive indicator for

R&D subsidiaries, as concerns the extent of their interaction with the external environment of the host location. The above findings come in contradiction with our initial argument in Hypothesis 3b.

Hypothesis 4 investigates how the level of autonomy given to the R&D subsidiary affects the degree of embeddedness with external host and internal networks. Taking into consideration our SURE estimates, none of these two hypothesized relationships are supported. However, the OLS estimates do find (as does previous literature) a negative association between the degree of autonomy and internal network embeddedness.

Considering Hypothesis 5, there is sufficient evidence to support the view that endowment's richness of the host country plays a significant role in determining the unit's embedded activity with the host country's external network. More precisely, the coefficient of the variable *Endowment* is found to be positive and significant, indicating that local endowment in terms of technological and scientific availability has a positive impact on developing ties with the external network of the host country.

In regard to other location specific characteristics influencing embeddedness with the external actors, we found that geographical distance is a factor that poses hazards in terms of establishing ties with the home country's network. Furthermore, a high market potential in the host location does not lead subsidiaries to establish stronger ties with the external host network. On the other hand, when market size is considerably large, subsidiaries seem to develop an even more tied relationship with their home (parent) network. Furthermore, UK subsidiaries seem to be more exposed to the host external network rather than to the home external and internal one. Concerning our firm-level control variables, the age (years of operation) of the R&D unit is a factor which positively and significantly influences the development of ties

with the home country's external network. On the contrary, R&D units associated with other production subsidiaries are not likely to establish strong connection with the external networks of the home country. Finally, as concerns our industry dummies the estimates provide evidence that subsidiaries operating in the Chemicals and Petroleum industry are more likely to establish ties with the external host network, while the opposite holds for Pharmaceuticals, which are more close to the external home environment and less tied with the internal network of the MNE. The following table (Table 7) summarises the hypotheses tested in this study, while in the last column it is indicated whether each hypothesis has been finally supported or not, according to the estimates of the SURE.

--- Table 7 goes about here ---

6. Discussion

Embeddedness is now widely accepted as the mechanism by which an R&D subsidiary of an MNE can access technological resources inside and outside the firm. However, understanding what sort of embeddedness will be used and when is crucial on evaluating how an MNE exercises leverage or arbitrage in locating its R&D activities based on location specific characteristics of the home and host locations, as well as the knowledge resources available in other parts of the MNE's network of subsidiaries. To this end, we suggested a broader framework and a more thorough exploration of existing data which recognised the interdependence of the alternative forms of embeddedness.

Our results show that external embeddedness in the home and host economies are largely complementary activities as are the external embeddedness in the home

location and internal embeddedness of the R&D subsidiary. A substitutive relationship exists between internal and external host embeddedness.

Different factors are associated with the three types of embeddedness. Among the factors that are associated with different types of embeddedness we find a strong role for the difference in mandates. Support laboratories (SLs) are more likely to be strongly embedded in the host economy. MNE subsidiaries make links with the external actors of the host location in order to better and more effectively distribute and position their products in foreign markets. Mandates for conducting more independent and original (novel) research (IILs) are more strongly associated with embeddedness in the external network of the parent firm in the home country. To the extent that new, basic research is likely to be associated with many positive externalities, the parent would like to keep control and oversight over such research. These findings and arguments are consistent with Patel (2010) and Patel and Pavitt (1991) for original and new technology creating activities.

Environmental uncertainty, is likely to drive hedging behaviour on the part of the MNE and in their presence, R&D subsidiaries will seek to establish stronger ties with the MNE's home external network, thus deepening home embeddedness. This is consistent with the known fact about FDI which is that operating in a location with few weaknesses in its political and economic infrastructure is a factor of crucial importance for MNEs. Interestingly, and in contradiction to the already established theory, there is evidence that a strong IPR protection regime influences negatively the decision to be embedded in the host external network. One explanation for this is the widely observed fact that MNEs embed themselves in host environments to avail of spillovers of various kinds and strong IPR regimes may prevent such spillovers from being exploited rapidly and without litigation. Finally, as we expected and is predicted

by the international business literature, rich scientific and technological endowment of a location is associated with greater host embeddedness.

Another issue that should be discussed is the group of findings around the relationship between autonomy and embeddedness. We find autonomy is not really associated with either external host embeddedness or internal embeddedness. This result, is in line with the finding of Taggart and Hood (1999) who found an insignificant relationship among the level of subsidiary's autonomy and the degree of its embeddedness within the local context. Even though R&D subsidiaries are sometimes in position to act more independently, in many cases the vulnerable asset named 'innovation' poses hazards to subsidiaries' managers and scientists as regards the degree of collaboration and interaction with other external actors. Even more interesting is that there is no trade-off between autonomy and internal embeddedness although in our estimations of the simple OLS model we do find a trade-off as suggested by the existing literature (Andersson and Forsgren, 1996; Birkinshaw and Morrison, 1995).

7. Summary and implications

The advantages of an MNE are closely tied to the different locations from where the multinational operates and its ability to leverage the benefits of location into a firm specific competence which is unique and inimitable. This is also the case when investments are in R&D rather than production or marketing. The mechanism by which firms draw on regional and own advantage is through embeddedness and a novel feature of our paper is the consideration of all forms of embeddedness and exploring the relationship between them.

We find the three forms of embeddedness we have considered to be strongly related to each other but associated with slightly different types of factors. This suggests MNEs do choose the amount of embeddedness selectively and the ability to embed confers a flexibility to MNEs that is not available to other types of firms.

Our conclusions are of course limited by the nature of our data which are limited in two ways. First, they are dated to the early nineties and it is possible that some of the relationships we have observed have atrophied or been overtaken by technology. This is particularly the case for internal embeddedness which may now be rendered easier due to the use of information technology and better knowledge management practices within the firm. A second limitation is that our data are cross sectional rather than panel and so we cannot control very well for the heterogeneous abilities of parent-subsidiary pairs or for the evolution of embeddedness over time.

Nevertheless, given the rising interest in the geographic distribution of R&D and company strategies to realise greater value from such investments, these limitations also provide a menu of future research possibilities and we hope the framework and methodology proposed here will prove useful to those enquiries.

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TABLES

Table 1. Cross-tabulation table between parent and host locations.

		Overseas locations where R&D subsidiaries operate														
		AU	**AT**	**BE**	**CA**	**CH**	**ES**	**FR**	**GE**	**IT**	**JP**	**NL**	**SE**	**UK**	**US**	**Total**
Headquarters locations	**CA**				N/A									3	1	4
	CH	1	1			N/A			2		1		1	1	10	17
	FR							N/A						1	5	6
	GE		1						N/A					1	17	19
	IT									N/A				1	1	2
	JP					1					N/A				5	6
	NL											N/A		2	3	5
	SE												N/A		3	3
	UK	1							2		1			N/A	15	19
	US	4		4	3	2	2	1	6	3		1		26	N/A	52
	Total	6	2	4	3	3	2	1	10	3	2	1	1	35	60	133
	Average age	39	22	23	17	31	25	15	46	32	2	35	27	28	25	26.2
	Average size	123	443	477	55	136	39	130	96	103	52	13	171	203	121	154.3

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Table 2. Industry composition of the survey data

Industry	Frequency	Percentage
Chemicals & Petroleum	50	37.0
Electronics	26	19.3
Pharmaceuticals	25	18.5
Miscellaneous	34	25.2

Table 3. Distribution of the initial population and the final sample.

Country / Region	Population of foreign R&D subsidiaries (N = 405)		Final sample of foreign R&D subsidiaries (N = 133)	
	Percentage	Population Number	Percentage	Population Number
Australia	3,21%	13	4,51%	6
Canada	6,67%	27	2,26%	3
Other European countries (Austria, Belgium, Spain)	4,44%	18	6,02%	8
France	4,20%	17	0,75%	1
Germany	5,93%	24	7,52%	10
Italy	1,98%	8	2,26%	3
Japan	0,74%	3	1,50%	2
Netherlands	0,49%	2	0,75%	1
Sweden	0,49%	2	0,75%	1
Switzerland	2,96%	12	2,26%	3
UK	15,06%	61	26,32%	35
USA	49,38%	200	45,11%	60
Rest of world	4,44%	18	0,00%	0

Table 4. Pair-wise correlation matrix and VIFs scores

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	External_home	1																				
2	External_host	0.33	1																			
3	Internal	-0.04	-0.18	1																		
4	SLs	0.08	0.32	-0.24	1																	
5	LILs	0.01	0.21	-0.25	0.18	1																
6	IILs	-0.08	-0.26	0.19	-0.29	-0.42	1															
7	IPR_protection	-0.24	-0.09	-0.03	-0.14	-0.11	0.22	1														
8	Endowment	0.18	0.41	-0.24	0.19	0.22	-0.30	-0.13	1													
9	Autonomy	-0.21	-0.27	-0.02	-0.01	-0.24	0.43	0.15	-0.33	1												
10	Ln_Years	0.18	-0.02	0.09	0.04	-0.25	0.05	-0.17	-0.12	0.22	1											
11	Ln_Size	0.18	0.35	-0.15	0.24	0.39	-0.33	-0.09	0.14	-0.21	0.12	1										
12	Ln_Geo_distance	-0.30	-0.12	0.01	-0.08	-0.11	0.15	0.16	-0.13	0.13	0.11	-0.02	1									
13	Cultural_proximity	0.31	0.00	-0.03	0.23	0.01	0.01	-0.31	0.07	0.01	0.22	0.03	-0.08	1								
14	CP	-0.25	0.06	0.09	-0.18	0.07	-0.11	0.10	0.01	-0.13	-0.13	0.04	0.12	-0.20	1							
15	EC	0.06	-0.06	-0.08	-0.01	0.09	-0.01	-0.11	0.03	0.01	-0.07	-0.08	-0.10	0.06	-0.36	1						
16	PH	0.18	0.14	-0.19	0.25	0.23	-0.23	-0.11	0.18	-0.03	0.10	0.13	-0.05	-0.02	-0.37	-0.22	1					
17	US	0.19	-0.00	0.06	0.09	0.05	-0.02	-0.65	0.00	-0.02	0.21	0.09	0.13	0.33	-0.20	0.18	0.16	1				
18	UK	-0.11	-0.09	-0.03	0.01	-0.14	0.13	0.23	-0.05	0.09	0.03	-0.10	0.00	0.34	0.12	-0.13	-0.03	-0.32	1			
19	Production_subsidiary	-0.23	-0.17	0.14	-0.12	-0.15	0.31	0.07	-0.22	0.29	0.13	-0.27	0.09	-0.16	0.02	-0.06	-0.12	-0.00	0.08	1		
20	Ln_GDPPC	-0.25	-0.07	-0.12	-0.23	-0.14	0.16	0.64	-0.06	0.12	-0.17	-0.10	0.21	-0.33	0.17	-0.13	-0.18	-0.64	0.26	0.11	1	
21	Macro_Instability	0.21	0.03	0.13	0.20	0.13	-0.14	-0.55	0.06	-0.13	0.17	0.03	-0.02	0.31	-0.13	0.09	0.12	0.58	-0.25	-0.10	-0.85	1
	VIFs (1)	-	1.37	1.33	-	-	1.70	-	-	-	1.50	1.44	1.27	2.51	2.18	1.64	2.08	2.12	1.93	1.43	6.30	5.44
	VIFs (2)	2.06	-	1.83	1.54	2.37	-	2.44	1.89	1.67	1.79	1.78	1.53	2.59	2.37	1.96	2.89	3.02	2.01	1.56	2.21	-
	VIFs (3)	1.68	1.58	-	-	-	-	2.15	-	1.46	1.57	1.44	1.41	2.20	2.15	1.63	1.74	2.70	1.66	1.47	1.78	-

Table 5. Data sources and descriptive statistics

Variable	Number of items used	Cronbach's alpha (α)	Source	Type	N	Mean	SD	Min	Max
Dependent Variables									
External Home	3	0.65	Survey	Scale	125	2.13	0.49	1	3
Extenal Host	6	0.60	Survey	Scale	113	1.79	0.33	1.16	2.66
Internal	8	0.71	Survey	Scale	126	1.84	0.38	1	2.75
Explanatory Variables									
SLs			Survey	Categorical (1-3)	121	2.22	0.75	1	3
LILs			Survey		119	1.94	0.74	1	3
IILs			Survey		124	1.88	0.88	1	3
IPR Host			W.G. Park (2008)	Scale	14	3.57	0.55	2.35	4.14
Macroeconomic instability			International Labour Organization & WDI	Scale	14	0.11	0.03	0.04	0.23
Autonomy	4	0.73	Survey	Scale	129	1.86	0.45	1	3
Local Endowment	4	0.72	Survey	Scale	123	1.73	0.54	1	3
Control Variables									
LnYears			Survey	Scale	114	2.95	0.93	0.69	4.82
LnSize			Survey	Scale	109	4.14	1.36	1.38	7.54
Production Subsidiary			Survey	Dummy	127	0.68	0.46	0	1
LnGeographical Distance			CEPII Database	Scale	14	8.55	0.80	5.83	9.74
Cultural Proximity			CEPII Database	Dummy	14	0.42	0.49	0	1
LnGDP per capita			WDI (World Bank)	Scale	14	9.84	0.19	9.24	10.24

Table 6. Seemingly Unrelated Regression Equations (SURE)

	Regressors	External Home	External Host	Internal
Hypotheses				
H1	External_home		0.48*** (0.07)	0.34*** (0.10)
	External_host	0.92*** (0.13)		-0.70*** (0.13)
	Internal	0.39*** (0.12)	-0.31*** (0.08)	
H2	SLs		0.11*** (0.03)	
	LILs		0.07 (0.05)	
	IILs	0.13** (0.06)		
H3	IPR_protection_regime		-0.12* (0.07)	-0.14 (0.10)
	Macro_Instability	3.84* (2.29)		
H4	Autonomy		-0.10 (0.07)	-0.12 (0.10)
H5	Endowment		0.11* (0.06)	
Control variables				
Firm level	Ln_Years	0.14*** (0.05)	-0.04 (0.03)	-0.03 (0.05)
	Ln_Size	-0.00 (0.03)	0.00 (0.02)	0.00 (0.03)
	Production_subsidiary	-0.34*** (0.10)	0.11 (0.06)	0.09 (0.09)
Industry level	CP	-0.15 (0.12)	0.16* (0.08)	0.07 (0.11)
	EC	0.13 (0.13)	-0.08 (0.09)	-0.16 (0.12)
	PH	0.31** (0.15)	-0.20* (0.11)	-0.34*** (0.13)
Country level	US	-0.10 (0.11)	0.01 (0.09)	0.05 (0.12)
	UK	-0.34* (0.17)	0.39*** (0.12)	0.49*** (0.16)
	Ln_Geo_distance	-0.15*** (0.05)	0.09** (0.04)	0.04 (0.05)
	Cultural_proximity	0.07 (0.12)	-0.08 (0.08)	-0.15 (0.11)
	Ln_GDPPC	1.13** (0.45)	-0.36* (0.18)	-0.77*** (0.24)
	Constant	-10.84** (4.71)	4.16** (1.92)	10.44*** (2.37)
	Parameters	15	18	15
	Chi2	115.99***	143.81***	59.33***
	R-squared	0.51	0.53	0.31

*** p < 1% ** p < 5% * p < 10% (S.E. in parentheses)

Table 7. Summary and support of hypotheses

Hypotheses		**Supported or Not supported**
H1a	External network of the home country and external network of the host country under which foreign R&D subsidiaries are embedded will have a complementary relationship in the sense that more of one type of embeddedness will give rise to more of the other type of embeddedness.	Supported
H1b	External network of the home country and internal network under which foreign R&D subsidiaries are embedded will have a complementary relationship in the sense that more of one type of embeddedness will give rise to more of the other type of embeddedness.	Supported
H1c	External network of the host country and internal network under which foreign R&D subsidiaries are embedded will have a substitutive relationship in the sense that more of one type of embeddedness will result to less of the other type of embeddedness.	Supported
H2a	Foreign R&D subsidiaries acting as IILs will be embedded in the home (parent) country's external network.	Supported
H2b	Foreign R&D subsidiaries acting as SLs and LILs will be embedded in the host location's external network.	Supported
H3a	Foreign R&D subsidiaries operating in a host environment embraced by high macroeconomic instability will be embedded in the home (parent) country's external network.	Supported
H3b	Foreign R&D subsidiaries operating in an environment which has a strong IPR protection regime will be embedded in the host country's external network, while R&D subsidiaries surrounded by a weak IPR protection regime will be embedded in the MNE's internal network.	Not supported
H4	Foreign R&D subsidiaries acting as more autonomous (i.e. decentralised) units will be embedded in the host location's external network, while R&D subsidiaries acting as less autonomous (i.e. centralised) units will be embedded in the MNE's internal network.	Not supported
H5	Foreign R&D subsidiaries operating in host locations with strong technological endowments will be embedded in the host country's external network.	Supported

APPENDIX

Table A1. Correlation of residuals

		1	2	3
1	Residual External home	1		
2	Residual External host	-0.31	1	
3	Residual Internal	-0.05	0.12	1

Table A2. OLS regression with adjusted S.E. for 14 clusters (Host country)

		External Home	External Host	Internal
Hypotheses				
H1	External_home		0.31** (0.11)	0.04 (0.21)
	External_host	0.51*** (0.14)		-0.17 (0.11)
	Internal	-0.00 (0.14)	-0.08 (0.08)	
H2	SLs		0.15** (0.06)	
	LILs		0.08** (0.03)	
	IILs	0.14* (0.06)		
H3	IPR_protection_regime		-0.13 (0.08)	-0.03 (0.05)
	Macro_Instability	5.69** (2.54)		
H4	Autonomy		-0.10 (0.07)	-0.11* (0.06)
H5	Endowment		0.15*** (0.05)	
Control variables				
Firm level	Ln_Years	0.12** (0.04)	-0.01 (0.02)	0.01 (0.02)
	Ln_Size	-0.00 (0.02)	0.00 (0.01)	-0.01 (0.01)
	Production_subsidiary	-0.30** (0.10)	0.05 (0.07)	0.00 (0.06)
Industry level	CP	-0.06 (0.11)	0.16* (0.08)	-0.03 (0.16)
	EC	0.06 (0.11)	-0.04 (0.08)	-0.17 (0.10)
	PH	0.24 (0.14)	-0.13 (0.16)	-0.36*** (0.07)
Country level	US	-0.06 (0.09)	-0.01 (0.15)	0.11 (0.10)
	UK	-0.07 (0.14)	0.31*** (0.08)	0.30** (0.13)
	Ln_Geo_distance	-0.18** (0.06)	0.07*** (0.01)	-0.01 (0.03)
	Cultural_proximity	0.13 (0.11)	-0.05 (0.09)	-0.22* (0.11)
	Ln_GDPPC	1.09** (0.44)	-0.16 (0.22)	-0.67*** (0.11)
	Constant	-9.03 (4.30)	2.13 (2.54)	9.31** (0.96)
	R-squared	0.47	0.60	0.25

*** p < 1% ** p < 5% * p < 10% (Robust S.E. in parentheses)