How remote are R&D labs? Distance factors and international innovative activities

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Abstract

This paper shows that value creation by multinational enterprises (MNEs) is the result of activities where geographic distance effects can be overcome. We submit that geographic distance has a relatively low impact on international research and development (R&D) investments, owing to the spiky nature of innovation, and to the unique ability of MNEs to absorb and transfer knowledge on a global scale. On the one hand, MNEs need to set up their labs as close as possible to specialized technology clusters where valuable knowledge is concentrated, largely regardless of distance from their home base. On the other, MNEs have historically developed technical and organizational competencies that enable them to transfer knowledge within their internal networks and across technology clusters at relatively low cost. Using data on R&D and manufacturing investments of 6320 firms in 59 countries, we find that geographic distance has a lower negative impact on the probability of setting up R&D than manufacturing plants. Furthermore, once measures of institutional proximity are accounted for, MNEs are equally likely to set up R&D labs in nearby or in more remote locations. This result is driven by MNEs based in Triad countries, whereas for non-Triad MNEs the effect of geographic distance on cross-border R&D is negative and significant.

journal of International Business Studies (201 3) **44,** 649-675. doi: 10.1057/jibs.2013.30

Keywords: cross-border investments; geographic distance; institutional distance; innovation and R&D

INTRODUCTION

It is widely acknowledged that research and development (R&D) activities play a fundamental role in firms' value creation (Morck & Yeung, 1991; Mudambi, 2008). This is among the reasons that have induced firms to keep the bulk of R&D activities close to their headquarters (Patel & Pavitt, 1991; Patel & Vega, 1999; Picci, 2010). However, there is extensive evidence that multinational enterprises (MNEs) are increasingly carrying out R&D and innovative activities in foreign locations (Dunning & Lundan, 2009; Narula & Zanfei, 2005; UNCTAD, 2005). Whereas, in an earlier phase, such foreign R&D activities were aimed mainly at adapting products to the local markets, in recent years an increasing number of R&D labs have been set up abroad in order to tap into the pool of competences of the host locations (Cantwell, 1995), and in many cases subsidiaries' mandates have evolved into competence creation rather than competence exploitation (Cantwell & Mudambi, 2005).[1]

Received: 26 November 2011
Revised: 28 April 2013
Accepted: 7 May 2013
Online publication date: 11 July 2013

This paper relates to this stream of literature, and investigates the extent to which geographic distance between the headquarters (in the home country) and the host location is an obstacle when MNEs decide to set up R&D labs abroad. In this perspective, we also relate to a large literature in international business (IB) addressing the role of distance as an obstacle to cross-border MNEs activities. Rather surprisingly, these studies focused mainly on relatively less value-creating activities, such as manufacturing and sales activities. Much less is known on the extent to which distance is also an obstacle in locating the more value-creating activities, such as R&D. This appears to be a key question in IB, since there is evidence that value creation in MNEs is relying increasingly on R&D activities conducted in competence-creating subsidiaries abroad. By investigating the location of cross-border R&D investments, this paper shows that value creation by MNEs is the result of activities where geographic distance effects can be overcome.

Indeed, we argue, and empirically show, that the creation of R&D labs is less geographically bound than activities that are less value creating, such as manufacturing. What really matters, when value creation is at stake, is not so much the geographic separation between home and host countries, but rather other distance (proximity) factors, including institutional differences (or similarities), which may act as fundamental barriers (or connectors) between parties involved in R&D investment decisions. We maintain that MNEs exploit techniques, routines, organizational structures and capabilities to generate value by integrating place-based advantages and characteristics across space (Beugelsdijk, McCann, & Mudambi, 2010).

Our conceptual framework builds on three distinctive features of cross-border investments aimed at the transmission and generation of knowledge. First, the spiky nature of innovation - that is, the geographic concentration of the centers of excellence in technological clusters - induces MNEs to set up their labs as close as possible to these locations and gain access to knowledge spillovers, largely regardless of distance from their home base.

Second, MNEs have pioneered techniques to codify, process and transmit knowledge, and they have developed routines and organizational structures that favor the transfer of (codified and tacit) knowledge across national boundaries and within their internal networks, thus reducing the cost of setting up R&D facilities in remote locations.

Third, institutional barriers, more than the costs of traversing physical distance, play a role in the absorption of knowledge that is being generated in unfamiliar locations.

Consistent with this framework, our empirical evidence - based on data on investment projects of some 6230 firms from 59 countries over the period 2003-2008 - suggests that geographic distance is less of an obstacle to the location of R&D labs than it is for manufacturing plants. In particular, once we account for institutional differences, measured in terms of languages, religious attitudes, legal systems and trade and investment regimes, we find that it is equally likely that R&D activities are set up in locations geographically near or far away from the home country.

The remainder of this paper is organized as follows. We first review extant literature on the role of distance factors in international transactions in general, and in the case of R&D foreign direct investments (FDIs) in particular. On the basis of different streams of theoretical and empirical contributions, we then develop a framework for the analysis of decisions concerning international location of R&D activities. We subsequently illustrate the data, conduct several econometric exercises and perform various robustness checks to test the impact of distance factors in the case of high-value-creating activities, such as R&D FDI, and compare these with lower-value-creating activities, such as cross-border investments in manufacturing. Conclusions will be drawn based on the empirical and theoretical work conducted in this paper.

PREVIOUS LITERATURE

The role of distance factors has been examined extensively in trade literature as well as in IB studies, but it has received much less attention in the analysis of cross-border R&D and innovation activities.

The international trade literature has assigned a pivotal role to geographic distance as a "catch-all" variable underlying various barriers to economic transactions. This is a key feature of the abundant theoretical and empirical literature on the gravity equation initiated with Tinbergen (1962) to interpret bilateral trade flows. More recently these models have been extended to explain all sorts of cross-border economic transactions, such as FDI (e.g., Egger & Pfaffermayr, 2004a; Kleinert & Toubal, 2010), and even the exchange of "weightless" goods such as financial assets (Portes & Rey, 2005), business services (Head, Mayer, & Ries, 2009) and digital goods consumed over the Internet (Blum & Goldfarb, 2006). Once the size (and other characteristics) of the countries (Tinbergen's "economic attractors") have been accounted for, the negative effect of distance on bilateral economic transactions is one of the most robust findings in economics (Anderson, 2011; De Benedictis & Taglioni, 2011; Learner & Levinsohn, 1995), and appears to persist over time (Disdier & Head, 2008).

As Tinbergen (1962) posited, geographic distance can be considered a rough measure of transportation costs and/or as an index of uncertainty and information costs that firms bear to enter foreign markets. However, associating such a wide variety of cost categories with a single variable such as geographic distance might simplify the job for correlation hunters, but is hardly satisfactory from an analytical point of view. Several contributions in international trade have acknowledged the specific role of cultural and social barriers in international trade, which should be analytically distinguished from geographic distance (Casella & Rauch, 2003; Frankel & Rose, 2002; Guiso, Sapienza, & Zingales, 2009; Huang, 2007).

The multidimensional nature of distance/proximity factors and the importance of non-geographic barriers/connectors have been particularly emphasized and explicitly acknowledged in IB studies. Empirical work in this field has extensively used proxies based on Hofstede's (1980) dimensions of national culture (masculinity, individualism, power distance and uncertainty avoidance) as a key additional dimension of distance.[2] Other studies have argued that these measures do not capture the variety of social, political and economic diversities across countries that affect transnational information flows, and hence influence cross-border transactions. These works have increasingly emphasized differences in languages, religious attitudes, legal systems, levels of industrial development, regulatory and trade regimes, travel and living inconveniences as key factors inhibiting international exchanges and FDI (Berry, Guillen, & Zhou, 2010; Dow & Karunaratna, 2006; Dunning & Lundan, 2008; Evans & Mavondo, 2002; Ghemawat, 2001; Schotter & Beamish, 2013; Shenkar, 2001). The increasing attention paid to these non-geographical distance factors is reflected in a proliferation of terms by which the wide variety of barriers to internationalization are identified and measured, including "unfamiliarity" (Grossman, 1996; Huang, 2007), "perceptual distance" (Ellis, 2008), "psychic distance stimuli" (Beckerman, 1956; Dow & Karunaratna, 2006; Hakanson & Ambos, 2010) and "institutional distance" (Abdi & Aulakh, 2012; Dunning & Lundan, 2008; Salomon & Wu, 2012; Xu, Pan, & Beamish, 2004).[3] The last terminology will be used in this paper - except when expressly citing works using a different jargon - as the concept of "institutional distance" appears to be a general and comprehensive way to identify transnational differences in terms of formal and informal rules, incentive structures, enforcement mechanisms and voluntary behavioral initiatives that will ultimately affect firms choices (Dunning, 2009: 24).[4]

Several works adopting a multidimensional approach to distance have highlighted that the mix of barriers and connectors varies according to the transnational activity that is being considered. The impact of individual components of distance has been found to be different according to the nature of the goods or sectors involved (Ghemawat, 2001), to the characteristics and motivations of investing firms (Nachum & Zaheer, 2005), to market-seeking (horizontal) vs efficiency-seeking (vertical) FDI (Slangen & Beugelsdijk, 2010) and to the characteristics of affiliates in foreign markets (Berry et al., 2010; OECD, 2011). In particular, the last appears to be a promising line of research, as it helps separate the impact of distance factors according to the nature of activities being carried out in foreign markets. This paper embraces this perspective, and in this regard it is related to the work of Berry et al. (2010) and Slangen and Beugelsdijk (2010) on the role of different distance dimensions in the foreign entry strategies of US multinationals. We share with these studies the attempt to distinguish the impact of various indicators of institutional distance, together with traditional geographic separation measures, on location decisions of different types of MNE activities. However, whereas both Berry et al. (2010) and Slangen and Beugelsdijk (2010) focus on less value-creating activities, such as manufacturing and commercialization/distribution, our work focuses on the role of geographic and institutional distance on the location of more value-creating activities, such as R&D.

The extensive literature on the internationalization of R&D and innovation has devoted scanty and most often lateral attention to the role of distance. Although there is ample evidence on the firm-level determinants of firms' decisions to offshore R&D and innovation activities, on home-country characteristics, and on the host-country attractors affecting such activities (e.g., Alcácer, 2006; Ambos & Ambos, 2011; Belderbos, Lykogianni, & Veugelers, 2008;

Berry, 2006; Cantwell & Piscitello, 2005; Criscuolo, Narula, & Verspagen, 2005; Le Bas & Sierra, 2002; Lewin, Massini, & Peeters, 2009), a comprehensive theoretical understanding of how distance affects R&D location is still largely missing. Nevertheless, several studies have developed useful insights into this issue. Howells (1990) uses scattered evidence to illustrate that the development of computer communication networks has provided relatively cheap, fast and effective means of communicating structured technical information between sites within companies, and hence reducing the hampering impact of distance in R&D internationalization. However, Howells (1990) also stresses that significant differences exist in the information and communication needs of the various types of R&D, which may lead to different locational requirements. Kuemmerle (1997) reflects on the results of a survey of global research networks of 32 US, Japanese and European MNEs, and concludes that the imperative to keep strategy development and R&D labs in close geographical proximity does not hold any more as firms face increasing pressures toward global technology sourcing, and to commercialize ever-new products around the world. He also highlights that location decisions will differ between home-base-augmenting R&D, which needs to be set up where scientific excellence is available, and home-base-exploiting R&D, which should be placed close to the company's manufacturing and marketing sites. In more general terms, Dunning (2009) has stressed that, as knowledge spreads across national boundaries, greater attention should be paid to the location of different parts of the value chain of the MNE, and of R&D in particular. He places this view in the context of a comprehensive reconsideration of the concept of distance: along with the costs of traversing physical distance, firms face the costs of dealing with different corporate and national institutional regimes, and the latter costs play a greater role in the case of knowledge-intensive industries.

While it is generally acknowledged that distance is potentially damaging to knowledge relationships, as it may create barriers to communication and mutual understanding between the parties involved (Goodall & Roberts, 2003), a few have explored the different mechanisms available to manage international knowledge transfer (Martin & Salomon, 2003), and have addressed the issue of how these are themselves influenced by distance factors (Ambos & Ambos, 2009; Doz & Santos, 1997). From this perspective, it has been argued that technology-based coordination mechanisms are relatively insensitive to spatial distance, whereas personal coordination mechanisms relying on interactions between individuals are harmed by all aspects of distance, and by cultural and linguistic distance in particular (Ambos & Ambos, 2009).

A few additional works in this stream of literature have used distance factors as control variables in econometric analyses exploiting the increasing availability of data on the internationalization of innovative activity at the country and firm levels. Muralidharan and Phatak (1999) and Ambos and Ambos (2011), using survey data from US and German MNEs, both find evidence that cultural distance is a significant determinant of R&D activity in host countries. Ambos and Ambos (2011) claim that the uncertainty associated with explorations, along with the high risk involved in dispersing strategically important resources abroad, lowers the likelihood of setting up a knowledge-seeking laboratory in a culturally distant country, as opposed to a knowledge-exploiting investment. Conversely, Granstrand (1999), based on questionnaires to 24 Japanese and 23 Swedish firms, finds that internationalization of R&D in Japanese corporations was more supply led, with no indication that the choice of foreign countries was influenced by psychic distance. Granstrand (1999) even reports that, in several Japanese corporations, cultural differences turned out to be advantageous: R&D people with different cultural backgrounds and styles of thought were perceived as beneficial for creativity and speedier problem-solving.

It is worth mentioning that although Granstrand (1999) acknowledges that the various cost components related to spatial distance and cultural differences of various kinds should be treated separately, neither his work nor that by Muralidharan and Phatak (1999) and Ambos and Ambos (2011) controls for geographic distance. Moreover, all of these studies use only one synthetic indicator for either cultural or psychic distance.

Other works on the internationalization of innovation do control for geographic distance as well as other distance factors, but do not focus on R&D investment decisions. This is the case of Dachs and Pyka (2010) and Picci (2010), who employ foreign patent applications data as a measure of international inventive activities, and control for geographic separation (between the inventors/applicants) and language diversity. Using data from the European Patent Office (EPO) for the period 2000-2005, Dachs and Pyka (2010) find that geographic distance is negatively correlated to the number of foreign patents obtained, while language commonality positively affects cross-border inventive activity. Picci (2010) instead uses a broader range of indicators of cultural and social proximity, along with more traditional measures of geographical distance and language commonality, as determinants of international patenting activities. He finds that geographic distance has a negative effect on bilateral knowledge transfers across countries, whereas other measures of cultural and social proximity exert a positive and significant effect. Picci (2010) thus implicitly recognizes the multifaceted nature of distance, which is instead explicitly assumed in the present work. Moreover, our study uses an input measure of the globalization of innovation as R&D investment projects rather than a measure of output such as patents, and compares the role of distance factors in research and in manufacturing activities. R&D FDI is the main focus in the empirical work carried out by Py and Hatem (2009), who examine location choices concerning 737 R&D centers established in Europe over 2002-2006, as part of wider research also covering FDI in other functional areas. This study considers only two dimensions of distance - geographic separation between home and host countries, and language commonality - and finds that the latter has a positive impact on R&D, whereas the former has a positive or non-significant effect. Unlike this study, in our paper distance is the key explanatory variable, and its multidimensional nature is explicitly taken into account. Furthermore, our empirical analysis is based on a larger sample of firms, and has a broader geographical scope.

To summarize, this paper will add to the literature we have reviewed in three ways. First, we shall develop an interpretive framework to analyze the specific role of distance as a determinant of high-value-creating international activities, namely cross-border R&D investments. This implies building on some of the insights that emerge from extant literature, and organizing them into a coherent set of propositions concerning the role of this variable in R&D location decisions. From this perspective, our contribution will be to highlight that in the case of high-value-creating activities the hindering effects of geographic distance can be overcome much more easily than in the case of lower-value-creating activities. Second, we shall acknowledge the multidimensional nature of distance, and place it at center stage in our empirical analysis. This will mark a departure from previous works: while the issue of disentangling and empirically testing different facets of distance has been explicitly considered in trade literature and IB studies in general, it has not been emphasized in analyses of R&D internationalization, where distance has received limited attention, and is usually treated as a mere control variable. As we shall see, emphasizing the multifaceted nature of distance is crucial, as it will allow the important impact of non-geographic dimensions of distance to be highlighted in the case of R&D location decisions. To the best of our knowledge this has never been shown in extant literature. Third, we shall run extensive empirical tests based on a large sample of multinational firms, and of home and host countries. This should yield a more robust set of results with a higher level of generality than analyses that are based either on case studies or on smaller samples of data.

ANALYTICAL FRAMEWORK AND HYPOTHESES

Our interpretation of the links between distance factors and cross-border R&D investment decisions relies on three building blocks.

First, the high and increasing geographic concentration of knowledge, together with the need to be close to the clusters where knowledge is produced, implies that R&D may need to be set up in locations relatively more distant from the home country, than for less-value-creating activities, such as manufacturing. An established argument in the literature is that R&D is a very important value-creating activity, whereas manufacturing or standardized services (such as logistics or commercialization) provide a lower contribution to firm value (Morck & Yeung, 1991; Mudambi, 2008). By managing the location of R&D facilities, MNEs can enhance knowledge accumulation and value creation, particularly in the case of competence-creating activities (Cantwell & Mudambi, 2005). The tension toward knowledge absorption and creation spurs firms to concentrate their investment in sites with local conditions that are the most conducive to technology creation (Cantwell & Kosmopoulou, 2002). As a result, cumulative agglomeration processes take place, leading to spiky global innovation (Audretsch & Feldman, 1996; Cantwell & Iammarino, 2003; Florida, 2005), and to the creation of clusters where investors benefit from knowledge spillovers (Cantwell & Piscitello, 2005; Defever, 2006; Giarratana, Pagano, & Torrisi, 2005; Verspagen & Schoenmakers, 2004). These forces - which are related to the tacit nature of knowledge, to the development of local social capital and to the degree of firms' embeddedness in the local or regional innovation system (Lorenzen, 2007; Lorenzen & Mudambi, 2013) - play a distinctive role as economic attractors for cross-border, knowledge-intensive investments. This view is consistent with the recent evidence of R&D FDIs accruing to countries where high-quality scientific institutions and centers of excellence are located (Arundel & Geuna, 2004; Reddy, 2000; UNCTAD, 2005; von Zedtwitz & Gassmann, 2002).[5] As Mudambi and Swift (2012: 13) put it:

> Close proximity among R&D team members allows for close personal interaction, which fosters the creation and transfer of tacit knowledge. Geographical proximity is an important factor in the creation of a common language and code that facilitate communication within technical communities and define their boundaries.

From this perspective, R&D FDI is a means to get close to where knowledge is produced, and gain access to competitive assets (Cantwell, 1989; Cantwell & Mudambi, 2011; Meyer, Mudambi, & Narula, 2011).

We submit that the geographical concentration and specialization of such centers of excellence reduce the set of location choices available to firms that need to acquire a specific piece of knowledge. Clusters often represent worldwide centers of excellence in particular industries or technologies. Silicon Valley outside San Francisco is a well-known technological cluster of software development, Boston's Route 128 is a well-known biotech cluster, and Southern Germany has a renowned technological cluster for high-precision machinery (Mudambi & Swift, 2012). Florida (2005: 50) reports that 85% of the world's patents in 2002 went to the residents of just five countries, and claims:

> Scientific advance is even more concentrated than patent production. Most occurs not just in a handful of countries but in a handful of cities - primarily in the United States and Europe .... As far as global innovation is concerned, perhaps a few dozen places worldwide really compete at the cutting edge.

Therefore the set of location choices is narrower than, for instance, in the case of manufacturing activities, which are not necessarily restricted to locations where cutting-edge technology is available, and are likely to be attracted by more widespread conditions, such as an appropriate production environment (e.g., in terms of costs and/or quality of production factors and infrastructures), past sourcing relationships or commercialization opportunities. This consideration implies a higher probability that MNEs will need to choose distant locations for R&D labs. Indeed, as MNEs have mushroomed all over the world over recent years, it is only by chance that they will eventually have their home base placed within, or in proximity to, a technological cluster or center of excellence where the key technology they need can be sourced. Even in the case where a MNE has its home base in a technology cluster where it can gain access to relevant knowledge spillovers, the increasing complexity of technologies implies that it is highly unlikely that all the relevant technology will be available within that cluster, so that other bits of knowledge will have to be accessed somewhere else.

Second, MNEs are particularly well placed in the transfer of knowledge bits across clusters and between clusters and other locations where the MNEs themselves are active, even over long distances. For manufacturing activities, geographic distance between the home and the host country is associated with higher transportation costs, owing to the need to ship intermediate inputs - mainly physical goods[6] - to the foreign plants. Such transport costs are much less relevant when firms carry out R&D activities abroad, since in this case intermediate inputs are mostly knowledge bits. In order to set up labs where the relevant knowledge can be sourced, firms will need to ensure the transfer of both codified and tacit knowledge to and from the home base, and to and from different units of the multinational network. Advances in codification and transmission of knowledge have significantly reduced transmission costs in this specific area, and diminished the spatial constraints on the organization of innovative activities (Arora & Gambardella, 1994; Bartel, Lach, & Sicherman, 2009). This general trend toward the reduction of transmission costs, especially in the case of codified knowledge, is further reinforced in the case of MNEs, which have historically pioneered and mastered the use of ICT techniques (Cantwell & Santangelo, 1999; Santangelo, 2002). However, MNEs are also better off at organizing the transfer of tacit knowledge over long distances. Indeed, an extensive literature has emphasized that MNEs have developed a wide range of routines and organizational devices to transmit and share knowledge effectively across clusters, and within their internal networks of subsidiaries and research labs (Alcacer & Zhao, 2012; Castellani & Zanfei, 2006; Gupta & Govindarajan, 1991; Kogut & Zander, 1992; Meyer et al., 2011). Innovation-based competition is posing increasing pressure on MNEs to design and ameliorate their internal knowledge-sharing practices, so as to deal better with the challenges of distance (Ambos & Ambos, 2009). Exploring these organizational mechanisms, and how MNEs differ in terms of their adoption and implementation, is beyond the scope of this paper. It remains, though, that the widespread adoption of these organizational devices, and of new communication technologies, can be expected to shift the balance toward more remote locations in the case of R&D, as compared with less value-creating activities, such as manufacturing, where transport costs are not negligible.[7]

The two sets of issues raised so far - the increasing need to locate R&D labs into few knowledge clusters, and the relatively low (and decreasing) costs of transmitting knowledge within MNE networks - push in the direction of reducing the impact of geographic distance in cross-border R&D location decisions, relative to the less value-creating activities of MNEs, such as manufacturing. On the one hand, the high and increasing geographic concentration of R&D implies that firms looking for valuable sources of knowledge may have no choice but to set up R&D labs in remote locations. In other words, to exploit the advantages of proximity to where knowledge is produced, it may be necessary to locate R&D far away from the home base. On the other hand, MNEs have historically developed technical skills and organizational capabilities that facilitate the transmission of relevant knowledge at relatively low cost over long distances.

These considerations boil down to the following hypothesis:

Hypothesis **1**: Geographic distance has a lower negative impact on the likelihood of setting up R&D labs abroad, than on cross-border investment decisions to establish manufacturing plants.

The third building block of our interpretive framework has to do with *the role of institutional distance in the cross-border location of R&D.*

It is widely acknowledged that institutional distance will affect FDI location decisions by significantly increasing the cost of doing business abroad (Eden & Miller, 2004; Xu & Shenkar, 2002). From a transaction cost perspective, this implies emphasizing that dealing with unfamiliar institutions will imply higher contractual hazards, as foreign investors will be more exposed to hidden information risks and technological leakages, giving rise to higher uncertainty, free-riding, shirking and coordination costs (Henisz, 2000; James, 2001; Santangelo & Meyer, 2011).

Institutional distance also matters because it affects the dynamic efficiency of location decisions, and this is particularly the case for R&D FDI. Cross-country differences in terms of institutional factors particularly affect the transfer of managerial, organizational and technical practices from the parent company to subsidiaries, and the interpretation and absorption of relevant information at the level of local plants, branches or laboratories. For example, MNEs investing in a country with a similar language and culture can be expected to disseminate information about a new product or production process more easily (Davidson, 1980), and are more likely to absorb new ideas and innovative stimuli effectively from a local context (Zanfei, 2000).

What should be stressed is that institutional distance will not only affect knowledge flows occurring within the internal network - which are governed by well-developed communication networks and routines within MNEs, as we have mentioned earlier. It is rather the absorption and transfer of knowledge that occur between the MNE and its local counterparts that are particularly influenced by these factors. This knowledge is mostly tacit, and is both generated and transferred through personal interactions. As noted by Ambos and Ambos (2009), personal coordination mechanisms, relying on interactions between individuals, are mostly harmed by cultural and linguistic distance.

The higher the institutional differences between a MNE's home base and a given host country, the higher the cost of effective knowledge sourcing, owing to the difficulties in the creation of the common language and codes that are needed to enhance communication within technical communities.

To summarize, the combination of regulatory, normative and cognitive aspects implies that institutional distance will impact negatively on FDI location decisions, including those concerning the creation of R&D labs. Given the particular importance of cognitive mechanisms in the creation, absorption and transfer of knowledge, we may expect that institutional distance will have a particularly relevant impact as an inhibitor of cross-border investment decisions in the domain of R&D, relative to other value chain activities.

This leads to the following hypothesis:

Hypothesis 2: Institutional distance has a higher negative impact on the likelihood of setting up R&D labs abroad, than on cross-border investment decisions to establish manufacturing plants.

DATA AND SAMPLE

Our empirical analysis is based on investment projects made by 6230 firms into 59 countries over the period 2003-2008. Information on such investments is drawn from fDi Markets, an online database maintained by fDi Intelligence - a specialist division of Financial Times Ltd - which monitors cross-border investments covering all sectors and countries worldwide. Relying on media sources and company data, fDi Markets collects detailed information on cross-border greenfield investments (available since 2003). Data are based on the announcement of the investment, and are updated daily.[8] For each one of the over 60,000 projects (up to 2008), fDi Markets reports information on the investment, such as the industry and main business activity involved in the project, the location where the investment takes place (host country, regions and cities) and the name and location of the investing company (home). The database is used as the data source in UNCTAD's World Investment Report, and in publications by the Economist Intelligence Unit.

The sample of destination countries includes all OECD countries, plus those labeled as candidates (Russia) or enhanced engagement countries (Brazil, China, India, Indonesia and South Africa). We also included 19 additional emerging economies, which either attract or originate at least the same number of international projects as OECD countries with the lowest involvement in bilateral investments according to our data source. The overall set of countries covers around 90% of all investment projects included in fDi Markets and, more specifically, 97.5% of all R&D projects. The complete list of countries is: Algeria, Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Czech Republic, Chile, China, Denmark, Egypt, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malaysia, Mexico, Morocco, the Netherlands, New Zealand, Nigeria, Norway, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Tunisia, Turkey, UAE, the United Kingdom, the United States and Vietnam.

For the purpose of this paper, the main business activity of each project is a key piece of information. fDi Markets assigns each project into one of 18 business activities, spanning from sales/marketing (the largest category), to business services, manufacturing, logistics, testing and extraction, R&D, design, development and testing (DDT), headquarters and other activities. We focus on projects in R&D,[9] but we compare results with investment projects in other value-added activities. We use projects in manufacturing activities as our main benchmark, but we also perform robustness checks on investments in other business activities different from R&D. In particular, we shall show results using the subset of investments in DDT. The DDT activities are clearly related to R&D, but are closer to the commercialization of innovation, as opposed to the projects classified as R&D, which tend to be more upstream activities in the innovation process.[10]

Overall, we have 1339 investment projects in R&D and 11,976 in manufacturing activities. Table 1 reports the distribution of investment projects by destination area. China is the country with the largest share of incoming projects, both in R&D and in manufacturing, but the EU (including the 15 Western countries, labeled EU15, and the new Member States) is the largest recipient area. However, the relative importance of countries and economic areas tends to differ when we look at the distribution of R&D compared with that of manufacturing investments. Whereas the former are concentrated in EU15, China, India, South-East Asia and North America, the latter are relatively more frequent in new EU Member States and Latin America (as well as in China and South-East Asia).

Table 1 Distribution of the total number of investment projects in manufacturing and R&D, by geographical areas of destination, 2003–2008

Destination area	Main business activity			
	Manufacturing		R&D	
	N	Percentage	N	Percentage
EU15	1276	10.7	313	23.4
New members EU	2006	16.8	55	4.1
Other Europe	862	7.2	37	2.8
North America	937	7.8	130	9.7
Japan	49	0.4	27	2.0
China	2671	22.3	276	20.6
India	857	7.2	181	13.5
South-East Asia	1796	15.0	218	16.3
Latin America	854	7.1	29	2.2
Oceania	87	0.7	21	1.6
Africa and Middle East	581	4.9	52	3.9
Total	11,976	100.0	1339	100.0
Top five countries (in percentage)	46.2		52.3	
Herfindal–Hirchman index	0.136		0.156	

Source: Elaborations on fDi Markets.

Table 2 Distribution of sample firms, by geographical area

Area	Number of firms	Percentage of sample
EU15	2525	40.53
North America	1330	21.35
South-East Asia	700	11.24
Japan	634	10.18
Other Europe	315	5.06
China	174	2.79
India	136	2.18
Africa and Middle East	117	1.88
New Members EU	116	1.86
Oceania	113	1.81
Latin America	70	1.12
Total	6230	100

Table 3 Distribution of sample firms, by individual countries

Country	Number of firms	Percentage of sample
The United States	1149	18.44
Germany	650	10.43
Japan	634	10.18
The United Kingdom	331	5.31
France	287	4.61
Italy	284	4.56
Taiwan	191	3.07
Republic of Korea	183	2.94
Spain	182	2.92
Canada	181	2.91
China	174	2.79
Austria	160	2.57
Switzerland	148	2.38
India	136	2.18
The Netherlands	128	2.05
Malaysia	117	1.88
Sweden	106	1.7
Denmark	97	1.56
Australia	93	1.49
Belgium	93	1.49
Finland	93	1.49
Singapore	81	1.3
Hong Kong	74	1.19
Norway	61	0.98
Russian Federation	56	0.9
Israel	45	0.72
Turkey	42	0.67
Ireland	40	0.64
Brazil	39	0.63
Greece	36	0.58
Thailand	32	0.51
Czech Republic	31	0.5
Poland	30	0.48
Portugal	27	0.43
United Arab Emirates	25	0.4
New Zealand	20	0.32
Saudi Arabia	19	0.3
Mexico	18	0.29
Estonia	13	0.21
South Africa	13	0.21
Hungary	12	0.19
Indonesia	11	0.18
Luxembourg	11	0.18
Egypt	8	0.13
Iceland	8	0.13
Lithuania	8	0.13
Slovenia	8	0.13
Argentina	7	0.11
Philippines	7	0.11
Chile	6	0.1
Tunisia	6	0.1
Latvia	5	0.08
Bulgaria	4	0.06
Vietnam	4	0.06
Slovakia	3	0.05
Romania	2	0.03
Nigeria	1	0.02

An interesting fact emerging from Table 1 is that international R&D labs are more geographically concentrated than manufacturing plants. The top five destination countries attract 52.3% of the R&D investments, compared with 46.2% for manufacturing. The Herfindal-Hirchman index of concentration (based on the number of investments in each of the 11 economic areas in Table 1) is also higher for R&D than for manufacturing (0.156 vs 0.136). These results are somewhat consistent with the idea that global innovation is "spikier" than global manufacturing; or, in other words, there are fewer locations where firms may find it convenient to set up R&D labs than there are sites for carrying out manufacturing activities.

These 13,315 projects were carried out by 6230 firms. As revealed by Tables 2 and 3, more than 60% of these firms are based either in the EU15 (40.53%) or in North America (21.35%). Asian countries, including Japan and China, represent about a quarter of the sample. The United States is the individual nation with the largest number of firms (18.44%), followed by Germany, Japan and the major European countries (Table 3). In terms of sectoral distribution, Table 4 shows that firms are operating in a wide range of industries. The most represented sectors are industrial machinery, automotive, metals, electronics, food and chemicals. It is worth mentioning that fDi Markets does not provide information on the sectors of the investing firms, but only on the investment projects recorded. Thus we assume that each firm is active in all the sectors in which it has investment projects. This induces some double counting in Table 4, since the same firm may appear under more than one sector.

Table 4 Distribution of sample firms, by sector

Sector	Number of firms	Percentage
Industrial machinery, equipment and tools	692	11.1
Automotive components	538	8.6
Metals	495	7.9
Electronic components	453	7.3
Food and tobacco	449	7.2
Chemicals	390	6.3
Plastics	385	6.2
Textiles	256	4.1
Consumer products	251	4.0
Building and construction materials	218	3.5
Pharmaceuticals	199	3.2
Paper, printing and packaging	196	3.1
Software and IT services	173	2.8
Alternative/renewable energy	168	2.7
Semiconductors	153	2.5
Wood products	142	2.3
Consumer electronics	128	2.1
Medical devices	116	1.9
Automotive OEM	115	1.8
Biotechnology	114	1.8
Communications	113	1.8
Coal, oil and natural gas	112	1.8
Beverages	93	1.5
Business machines and equipment	80	1.3
Ceramics and glass	76	1.2
Aerospace	67	1.1
Rubber	67	1.1
Non-automotive transport OEM	62	1.0
Engines and turbines	52	0.8
Business services	50	0.8
Healthcare	35	0.6
Minerals	34	0.5
Space and defense	28	0.4
Real estate	26	0.4
Transportation	23	0.4
Financial services	21	0.3
Warehousing and storage	16	0.3
Leisure and entertainment	10	0.2

Note: Direct information on the sector of each is firm is not available, but we know in which sector each firm has investments. We exploit this information to assign each firm to one or more sector (in case it has investments in more than one sector).

Table 5 Number of sectors in which a firm has investment projects

	Number of firms	Percentage of sample
1	5096	81.8
2	696	11.2
3+	438	7.0
Total	6230	100

Table 6 Frequency of number of investments in manufacturing and in R&D by firm and destination country

Number of investments	Manufacturing		R&D	
	Frequency	Percentage	Frequency	Percentage
0	352,330	97.51	360,198	99.68
1	7456	2.06	1001	0.28
2–10	1532	0.42	141	0.04
10+	22	0.01	0	0.00
Total	361,340	100.00	361,340	100.00

However, as documented in Table 5, more than 80% of firms have investments in only one sector, so double counting is relatively limited.

When we consider the full matrix of data we have a total of 361,340 observations (6230 firms x 58 countries), but clearly the number of firm-destination country pairs with zero investments is huge, since firms do not invest in all the countries. Indeed, Table 6 shows that positive investments are less than 2.5% of all the observations for manufacturing projects, and only 0.32% for R&D projects. This suggests that the probability of a firm investing in a given country is very low. The challenge of this paper is to test the main determinants of this rare event, and in particular to assess the role of distance/proximity. Table 6 also reveals that more than 80% of the firm-country pairs where a positive number of investments is recorded have one project only. Thus, in the 6-year window of our data, repeated investments of a firm in a given country are only occasional. This induces us to try and explain not the extent of investment, but rather the binary choice of firms setting up a manufacturing or R&D facility in a given country. However, as a robustness check, we shall run regressions where the dependent variable is the count of the number of investments of a firm in a given country.

Table 7 provides some preliminary insights into the role of geographical proximity in explaining manufacturing vs R&D foreign investments. In particular, it reports the number of firms based in the EU15 and the United States investing in each destination area.[11] For EU firms it is clear that manufacturing activities are very sensitive to distance: more than 60% of all firm-country pairs where one (or more) production plant(s) has been set up are in close proximity to the home base (29.2% in New Member States, 14.5% in other EU15 countries, 9.4% in other European countries and 6.0% in neighboring countries in Africa and Middle East).

Table 7 Geographical distribution (percentages) of firms investing in manufacturing and R&D, by area of origin (EU15 and North America only) and destination

Area of destination	Area of origin					
	Manufacturing			R&D		
	EU15	NA	Total	EU15	NA	Total
EU15	14.5	14.8	12.3	27.5	26.5	25.6
China	11.8	20.2	17.6	15.5	15.5	17.3
South-East Asia	6.6	13.9	14.9	12.9	16.2	15.3
India	6.4	7.9	6.5	9.6	18.9	13.8
North America	8.3	6.9	7.8	12.0	4.0	9.8
New Member EU	29.2	10.6	18.8	7.3	4.6	4.7
Africa and Middle East	6.0	4.5	5.8	4.7	4.6	3.9
Other Europe	9.4	5.4	7.2	4.1	2.9	3.2
Latin America	6.7	13.8	7.7	2.9	2.5	2.4
Japan	0.5	1.0	0.5	2.9	1.9	2.2
Oceania	0.5	1.1	0.9	0.6	2.5	1.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

Note: For the sake of clarity, we report data from EU15 and North American firms only (which account for more than 60% of the sample). The complete table is available from the authors upon request.
Source: Authors' elaborations on fDi Markets data.

By contrast, R&D is much less likely to be located in nearby locations, since the same regions account for about 40%. North American firms show a similar pattern. For example, neighboring Latin American countries attract 13.8% of US firms' choices to set up manufacturing plants, but only 2.9% for R&D labs. By contrast, in more remote locations in Europe or India the probability that US firms will engage in some R&D investment is much higher relative to the choice of initiating production plants. Of course, these patterns may be explained by host-country-specific advantages (such as market size, cheap and/or skilled labor, technological leadership, taxation or agglomeration economies), by other bilateral differences between home and host country (possibly related to geographic distance) and/or by firm-level characteristics. We shall account for all these factors in the econometric analysis, which will be presented in the next section.

ECONOMETRIC ANALYSIS

Dependent Variable

Our dependent variable is a binary indicator taking the value 1 if a firm *i* based in country **5** has at least one investment project in activity / (in the period 2003-2008) in country *d*, and 0 otherwise.[12] Countries s and *d* belong to the group of 59 economies described above in "Data and sample". National investments (i.e., when *s* = *d)* are excluded, owing to the lack of such information from fDi Markets. We run separate regressions for j equal to Manufacturing and R&D. Given the dichotomous nature of our dependent variable, we estimate a probit model. In the robustness checks section we shall extend our analysis in various ways. In particular, we shall allow for interdependence in manufacturing and R&D investments; we shall benchmark our baseline estimation of the probability of investing R&D with other business activities, such as those labeled as DDT; and we shall go beyond an estimation of the extensive margin, using the number of investment projects of each firm in a given country as a measure of the intensive margin of investment, and estimate its determinants using negative binomial regressions.

Independent Variables

Bilateral variables

As previously stated, distance is a multidimensional concept, and its individual components have limited explanatory power when considered in isolation. Accordingly, in order to understand the complex process of internationalization, we include as independent variables a set of distance-related factors that may act as barriers (or connectors) between parties involved in FDI decisions.

The first variable we include is *geographical distance* between the home and host countries. We use a measure of geographic distance between home and host countries widely used in the literature and compiled by CEPII.[13] For each pair of home and host countries in our sample, the number of kilometers separating the largest cities is weighted by their size in terms of inhabitants as a share of the national population, and then averaged. This measure reduces the problems related to computing the distance between a specific city or point (such as the centroid) in each country, which for large economies can be distorting. Second, we control for the fact that countries that *share a border* are more likely to engage in bilateral economic relations. Third, we introduce a variable measuring *time differences.* As noted by Head et al. (2009) and Stein and Daude (2007), for any given geographical distance, differences in longitude may affect international investment decisions both positively and negatively. On the one hand, firms may exploit time differences to work around the clock. In the case of software, for example, it is not uncommon for researchers in the Western hemisphere to pick up the work of

Asian researchers when their work shift ends. On the other hand, the problem with this division of labor is that real-time communication is more difficult, and researchers would find it difficult to discuss any problem emerging in the process. Previous results for this variable are mixed: Stein and Daude (2007) find negative effects on aggregate FDI, whereas Head et al. (2009) find non-significant effects in the case of service offshoring.

We then augment our specification introducing variables capturing institutional distances and similarities between the home and host country. In particular, we control for *institutional commonalities,* such as sharing *colonial ties* and *legal origin* (same legal system, e.g., common law, civil law, customary law, Shariah, and combinations and subsets thereof) as well as being part of the same *regional trade agreement* (RTA), or having signed a *bilateral investment treaty* (BIT).[14] We expect that institutional similarities would increase familiarity and decrease uncertainty in economic transactions, thus acting as connectors, and increasing bilateral FDIs.

As measures of institutional distance, we also consider cultural and social differences, which we proxy using differences in *language* and *religion.* These variables should control for communication problems among economic actors and hence facilitate bilateral investments in R&D, as these involve important knowledge exchanges. Although language constitutes the medium allowing economic parties to exchange information (Melitz, 2008), knowledge flows would also require a great deal of cultural proximity. Since the moral values and behavioral codes that any religion advocates constitute an implicit and community-specific connector, religious similarities can breed cultural proximity and trust between individuals (Guiso et al., 2009; Hergueux, 2010; Iannaccone, 1998). Languages and religious beliefs affect the way people notice, categorize and interpret stimuli from the environment. We rely on measures of distance in religious attitudes and language differences, as computed by Dow and Karunaratna (2006) for a large sample of countries.

The indicator used to capture the distance in *languages* is based on differences between families of idioms (e.g., Altaic), branches (e.g., Germanic) and sub-branches (e.g., Transitional Scandinavian), specific languages within sub-branches (e.g., Norwegian). This index ranges from -3.868 (lowest distance, for countries whose major language belongs to the same family, branch and sub-branch, and the specific language itself is basically the same, e.g., the United Kingdom and the United States, or Argentina and Spain) to 0.526 (highest distance, for countries with different language, branch, sub-branch and family, e.g., Germany and China, or Mexico and Turkey).

The measure of distance in religions is built according to the family, divisions and sects they belong to. The highest distance is recorded when the major religions in a pair of countries belong to different families (e.g., monotheistic vs reincarnation based); the lowest distance is observed when religions belonging to the same family (e.g., monotheistic based) also belong to the same religion group (e.g., Christianity), the same division (e.g., Anglican) and the same denomination/sect (e.g., Baptist). A major religion is defined as any religion to which more than 20% of the population claims an affiliation. The variable used is a factor resulting from a principal component analysis of three basic indicators,[15] and takes values from -1.551 (religions of the home and host countries are very similar, as for Ireland and Spain, or Algeria and Morocco) to 1.528 (maximum difference, e.g., Israel and India, or Vietnam and Saudi Arabia).

Home and host-country characteristics

As many existing works have shown, the probability that a firm will set up manufacturing or R&D facilities in a given country clearly depends on several location-specific characteristics, such as proximity to large markets, to resources and technological inputs used in production and R&D, corporate taxes, cost of labor, quality of human capital, intellectual property rights protection and agglomeration economies (Alcacer & Chung, 2007; Basile, Castellani, & Zanfei, 2008; Nachum, Zaheer, & Gross, 2008). Thus, in order to be able to focus on the role of bilateral connectors and separators, we control for all possible host-country confounders by introducing a set of host-country fixed effects. Similarly, we want to avoid our results being driven by the higher propensity of some countries to invest abroad, so we introduce home-country fixed effects. The choice of country fixed effects does not allow us to identify any specific effect of home- or host-country characteristics, but it ensures that the effect of distance-related variables on cross-country investments is not confounded by some unobservable home- or host-country characteristic.

Firm-level characteristics

Finally, we also include a set of firm-level characteristics that may explain the propensity to engage in foreign investments. First, we include one variable accounting for the total number of investments of

Table 8 Variable source and description

Variable	Description	Non-zero observations (in percentage)	Mean	Standard deviation	Minimum	Maximum
FDI_Man	FDI project in manufacturing	2.23	0.034	0.278	0	34
FDI_R&D	FDI project in R&D	0.28	0.004	0.074	0	10
Geographical distance	Log of distance between the *n* major cities of *s* and *d* (weighted) (CEPII)		8.498	0.970	5.081	9.880
Frontier	=1 if *s* and *d* share a border		0.050	0.219	0	1
Time differences	Time difference between *s* and *d* (number of hours)		4.961	3.597	0	12
Colony	=1 if colonial ties existed between *s* and *d* (CEPII)		0.048	0.214	0	1
Legal origin	=1 if *s* and *d* share the same legal origin (CEPII)		0.203	0.402	0	1
RTA	=1 if *s* and *d* have a RTA (CEPII)		0.283	0.451	0	1
BIT	=1 if a BIT between *s* and *d* has initiated before 2000 (UNCTAD)		0.322	0.467	0	1
Language	Difference in language factor (Dow-Karunaratna)		−0.014	0.940	−4.346	0.526
Religion	Difference in religion factor (Dow-Karunaratna)		−0.060	1.014	−1.551	1.528
Firm R&D investment	Total number of investments of each firm in R&D		0.217	0.974	0	24
Firm manuf. investment	Total number of investments of each firm in manufacturing		1.925	3.962	0	115
Sectoral concentration	Index of sectoral concentration of each firms' investments (Herfindal index based on number of investments in each sector by each firm		0.914	0.192	0.092	1

each firm in R&D (or in manufacturing, according to which type of investment is set as the dependent variable), aiming to capture the overall propensity of each firm to engage in R&D (or manufacturing) activity abroad. This can also be thought of as an imperfect proxy for firm size. Second, we control for the fact that firms in some sectors may be more inclined to invest abroad, introducing a vector of 38 sector fixed effects. As we mentioned above in "Data and sample", we infer each firm's sector of activity from the industries in which it has made investments in manufacturing or R&D (according to fDi Markets), and we allow each company to be active in more than one industry. Third, we further control for sectoral diversification/concentration, building the Herfindhal index for the investments of each firm. The index is constructed from information on the firms' share of investments in each different sector, and takes the value 1 when a firm has investments in only one sector. Lower values of the index suggest higher diversification of a firm's investments in manufacturing and/or R&D activities across sectors. In the robustness checks section we shall extend our analysis to account for the fact that distance may play a different role for firms originating from the non-Triad countries.

The full list of variables, sources and descriptive statistics is given in Table 8.

Results

Table 9 reports the results from the probit regressions of the probability of a firm setting up a manufacturing or R&D facility in one of the 59 foreign countries in our sample.[16] As anticipated in the previous section, each estimation includes a vector of source and destination country dummies that are intended to capture the corresponding fixed effects - that is, the impact of the characteristics of the home country on the probability to invest abroad, and of the host country to attract investments. Results in Table 9 also include a measure of firms' international exposure (which is also a proxy for firm size) and a vector of sector fixed effects, which controls for the fact that firms in some industries have a higher propensity to invest abroad.[17] As mentioned earlier, controlling for these country-, firm- and sector-level fixed effects allows us to focus on the role of distance-related factors, aside from the fact that some countries originate or attract a higher number of investments, and some firms or sectors are more prone to international involvement.

Before commenting on the results any further, it is worth mentioning that Table 9 reports the

Table 9 Determinants of firms' international investments in R&D and manufacturing, 2003–2008, probit regressions

Dependent variable	R&D	Manufacturing	R&D	Manufacturing
Geographic distance	−0.768***	−1.135***	−0.019	−0.860***
	(0.256)	(0.092)	(0.244)	(0.101)
Frontier	−0.264	0.191	−0.615**	0.065
	(0.270)	(0.137)	(0.271)	(0.131)
Time difference	0.065	0.034*	0.067	0.034*
	(0.062)	(0.020)	(0.046)	(0.018)
Colonial ties			0.085	0.280**
			(0.255)	(0.123)
Common origin of legal system			0.205	0.209**
			(0.220)	(0.083)
RTA			1.748***	0.187
			(0.416)	(0.146)
BIT			0.247	0.178**
			(0.176)	(0.073)
Linguistic distance			−0.360***	−0.224***
			(0.100)	(0.046)
Religious distance			−0.339*	−0.338***
			(0.209)	(0.089)
Firm investing in R&D	0.455***		0.465***	
	(0.021)		(0.022)	
Firm investing in manufacturing		0.100***		0.096***
		(0.004)		(0.004)
Sectoral concentration	−3.070***	−1.916***	−3.060***	−1.849***
	(0.249)	(0.103)	(0.251)	(0.099)
Home fixed effect	Yes	Yes	Yes	Yes
Host fixed effect	Yes	Yes	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes
Log likelihood	−4890	−32,458	−4828	−31,570
Number of observations	316,538	403,332	310,677	354,768

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates are marginal effects.

marginal effects of each independent variable on the probability of a firm's investing (in R&D and in manufacturing, respectively) in a given country. More precisely, they are expressed as semi-elasticities, and they tell us the percentage change in probability due to a unit change in the independent variable considered. In the case of variables expressed in logarithms, such as geographic distance, the parameters can be directly interpreted as elasticities. Since we have observations for our 6230 firms in the 58 countries, but most explanatory variables (such as all the distance measures) vary only by source-destination country pair, each country pair will enter the sample multiple times, depending on how many firms come from the same home country. As a consequence, the residuals from the regressions will cluster by country pair, and the standard errors of the country-pair-specific explanatory variables could be substantially underestimated. To alleviate this issue, we report standard errors clustered by country pair.

Despite the very low number of non-zero observations,[18] the model performs rather well, as suggested by the pseudo R^2, which is as high as 36% for R&D investments and 24.5% for manufacturing FDI, and by the fact that all the variables have some explanatory power, in the former and/or the latter model. In the robustness checks section we shall deal with the issue of this high number of zeros.

Columns 1 and 2 illustrate the results of our baseline specification, wherein we test for the impact of geographic distance on the probability of a firm's engaging in cross-country R&D and manufacturing investment projects, respectively. Once we control for firm, sector and (home and host) country characteristics, but not conditioned on institutional distance, the probability of investing abroad is negatively correlated with geographic distance. This impact is very sizeable for manufacturing,[19] but it is much lower for R&D investments. This appears to support Hypothesis 1 developed in this paper.

In particular, it is consistent with the idea that, on the one hand, MNEs increasingly need to access knowledge where it is generated and concentrated, and, on the other hand, they are also increasingly able to do so, thanks to their investments in ICT, and in organizational devices that allow them to transfer knowledge within their internal networks effectively, largely regardless of geographic distance. We shall provide more insights into these mechanisms in the robustness checks section.

Columns 3 and 4 illustrate what happens when the baseline specification is augmented to accommodate institutional distance/proximity factors. It is shown that the probability of a firm's choosing a given foreign country in which to set up a research facility or manufacturing plant is negatively related to the measures of institutional distance used in our analysis (or, symmetrically, it is positively related to institutional proximity). That is, the probability is higher when the source and destination country share colonial ties, their legal systems have the same roots and principles, they are part of an RTA (such as the EU, NAFTA, Mercosur or ASEAN) or a BIT, and have relatively similar languages and religions.

Once institutional differences are accounted for, we find that the marginal effect of geographic distance drops by 0.75 (from -0.768 to -0.019), and becomes not statistically different from zero for R&D FDI. In other words, conditional on institutional differences, it is equally likely that firms will set up R&D facilities in nearby or in more remote locations. By contrast, even controlling for institutional proximity, nearby locations are still more likely to be chosen by firms establishing manufacturing plants abroad, since the marginal effect drops by only 0.27 (from -1.135 to -0.860). In the case of manufacturing investments, geographic distance retains a significant explanatory power, even after controlling for institutional distance, whereas this is not the case for R&D. This is consistent with Hypothesis 2 discussed earlier: institutional differences have more explanatory power for R&D than for manufacturing. Our interpretation of results is in line with Tinbergen's (1962) idea that geographic distance should capture both trade costs and the unfamiliarity of markets which are costlier to deal with. As geographic distance becomes non-significant for R&D once we control for institutional distance factors, which are our proxies for unfamiliarity, this implies that the most important obstacles to cross-border investment in R&D are the differences in the regulatory, normative and cognitive institutions characterizing (home and host) countries, rather than transportation costs and trade barriers. This does not apply to manufacturing, where the costs of traversing geographic distance are high and significant, even after controlling for institutional differences. Hence the latter have a lower impact as a barrier to FDI in manufacturing activities than in R&D (and vice versa).

ROBUSTNESS CHECKS

This section reports on various robustness tests. In particular, we shall show that:

(1) our results are not affected by multicollinearity problems; nor
(2) by the high percentage of zeros; nor
(3) by the dichotomous nature of our dependent variables.

Furthermore, we shall extend our analysis to:

(4) the study of interdependence between manufacturing and R&D activities;
(5) different benchmarks, such as the investments in downstream R&D activities (DDT); and
(6) different slices of the samples of firms.

Multicollinearity

The different facets of distance are obviously correlated. Table 10 shows that correlation is close to 0.8 between geographic distance, time differences and the RTA indicator. As we have shown in the previous section, because of this correlation, once we control for institutional differences, the effect of geographic distance on the probability of setting up R&D in a given location is not significantly different from zero. One may be concerned that this result is due to multicollinearity. On a closer look, this does not occur in our estimates; in fact, multicollinearity tends to inflate the standard errors. Instead, in our case, standard errors are almost unchanged: that associated with the geographic distance parameter goes from 0.256 in Column 1 to 0.244 in Column 3. Consistent with this interpretation, we find that the variance inflation factors (VIF) reported in the last column of Table 10 are under the limit of 10 recommended by Kennedy (1992), Neter, Wasserman and Kutner (1985) and Stundemund (1992), and the maximum value matches the stricter limit of 5.3 proposed by Hair, Anderson, Tatham, and Black (1999).

Dealing with the High Percentage of Zero Observations

A second concern that we want to deal with is the excessive number of zeros. One way to do this is to drop firms that do not have at least one investment

Table 10 Correlation matrix and VIFs

	1	2	3	4	5	6	7	8	9	10	11	12	VIFs
1. Geographic distance	1												5.32
2. Frontier	−0.430	1											1.36
3. Time differences	0.840	−0.283	1										3.60
4. Colony	−0.029	0.071	0.001	1									1.15
5. Legal origin	0.002	0.126	0.014	0.232	1								1.29
6. RTA	−0.779	0.315	−0.693	−0.027	0.023	1							2.70
7. BIT	−0.105	−0.082	−0.143	0.018	−0.093	0.060	1						1.06
8. Language	0.037	−0.239	−0.001	−0.316	−0.441	−0.082	0.160	1					1.56
9. Religion	0.350	−0.202	0.231	−0.105	0.005	−0.032	−0.017	0.285	1				1.33
10. Firm R&D investment	0.038	−0.005	0.060	0.013	0.005	−0.032	−0.017	−0.038	−0.024	1			1.14
11. Firm manufacturing investment	−0.004	0.001	−0.004	−0.000	−0.014	0.002	−0.004	0.020	0.019	0.326	1		1.28
12. Sectoral concentration	−0.025	0.009	−0.030	−0.007	0.011	0.030	0.021	−0.005	−0.033	−0.217	−0.398	1	1.20

Table 11 Robustness test: Dealing with the number of zeros, probit regressions

Dependent variable	R&D	Manufacturing	R&D	Manufacturing
Geographic distance	−0.653***	−1.098***	−0.097	−0.852***
	(0.191)	(0.089)	(0.207)	(0.101)
Frontier	−0.273	0.204	−0.527**	0.074
	(0.234)	(0.133)	(0.236)	(0.130)
Time difference	0.046	0.031	0.049	0.034*
	(0.044)	(0.019)	(0.036)	(0.018)
Colonial ties			−0.117	0.278**
			(0.220)	(0.123)
Common origin of legal system			0.172	0.205**
			(0.182)	(0.082)
RTA			1.170***	0.200
			(0.325)	(0.147)
BIT			0.296*	0.174**
			(0.159)	(0.073)
Linguistic distance			−0.312***	−0.222***
			(0.086)	(0.046)
Religious distance			−0.350**	−0.333***
			(0.172)	(0.088)
Firm investment in R&D	0.249***		0.255***	
	(0.013)		(0.013)	
Firm investment in manufacturing		0.091***		0.093***
		(0.004)		(0.004)
Sectoral concentration	−0.415**	−1.723***	−0.405**	−1.747***
	(0.199)	(0.096)	(0.202)	(0.096)
Home fixed effect	Yes	Yes	Yes	Yes
Host fixed effect	Yes	Yes	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes
Log likelihood	−3859	−31,643	−3805	−31,160
Number of observations	40,611	336,516	39,859	330,372

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates are marginal effects.

(in any country) over the period 2003-2008 in the specific activity considered. For R&D this means that, out of 6230 firms in our sample, only 752 set up R&D labs abroad, whereas 5802 firms set up manufacturing plants abroad. In Table 11 we replicate the two sets of probit regressions for R&D and

Table 12 Robustness test: Intensive margin and repeated investments, negative binomial regressions

Dependent variable	R&D	Manufacturing	R&D	Manufacturing
Geographic distance	−0.491***	−0.876***	0.013	−0.652***
	(0.148)	(0.071)	(0.159)	(0.086)
Frontier	−0.218	0.099	−0.444***	−0.022
	(0.174)	(0.097)	(0.172)	(0.096)
Time difference	0.037	0.032**	0.036	0.028**
	(0.037)	(0.015)	(0.030)	(0.014)
Colonial ties			−0.007	0.279***
			(0.177)	(0.096)
Common origin of legal system			0.124	0.200***
			(0.165)	(0.069)
RTA			1.070***	0.188
			(0.273)	(0.123)
BIT			0.114	0.044
			(0.124)	(0.067)
Linguistic distance			−0.219***	−0.157***
			(0.069)	(0.034)
Religious distance			−0.293**	−0.253***
			(0.139)	(0.076)
Firm investment in R&D	0.246***		0.250***	
	(0.021)		(0.021)	
Firm investment in manufacturing		0.073***		0.073***
		(0.004)		(0.004)
Sectoral concentration	−2.120***	−1.595***	−2.111***	−1.615***
	(0.147)	(0.083)	(0.148)	(0.081)
Constant	0.101	5.226***	−3.731**	3.582***
	(1.416)	(0.655)	(1.557)	(0.730)
Overdispersion parameter	0.806***	0.629***	0.800***	0.576***
	(0.313)	(0.169)	(0.302)	(0.167)
Home fixed effect	Yes	Yes	Yes	Yes
Host fixed effect	Yes	Yes	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes
Log likelihood	−5454	−37,591	−5399	−37,071
Number of observations	361,340	361,340	354,768	354,768

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates are marginal effects.

manufacturing investments on these subsamples. For R&D, the share of zero observations is now 97%. Results for these restricted samples are largely unchanged.

A different strategy to account for the high percentage of zero observations would be to estimate a rare event logit (King & Zeng, 2001). We pursued this empirical strategy as well, exploiting the user-developed program ReLogit available in the statistical package Stata, but the software returned an error message when we tried to estimate our specifications. The problem seems to lie in the high number of sectors and country fixed effects. Once we removed such vectors of dummy variables, ReLogit returned estimates in line with standard logit or probit models.[20] All in all, we feel reassured that the high number of zero observations should not drive our results.

Beyond a Dichotomous Choice: Intensive Margin and Repeated Investments

Our empirical analysis in the previous section is carried out by collapsing all the information on firm-country investments into a binary variable. In the section "Data and sample" we argue that this is done since, as revealed by Table 6, out of 1142 firm-country observations where at least one R&D lab was set up in the period 2003-2008, only 141 firms (12.3%) set up more than one lab. Therefore repeated investments in R&D are a very rare phenomenon, which, although interesting from a theoretical point of view, does not appear to be very relevant from an empirical point of view. This is probably due to the relatively short timespan of our data. Nevertheless, it is worth investigating whether the role of distance changes when we take into

Table 13 Robustness test: Interdependence between manufacturing and R&D investments

	Bivariate probit		Probit	
	R&D	Manufacturing	R&D	Manufacturing
Firm has investment in manufacturing in country *j*			1.568***	
			(0.178)	
Firm has investment in R&D in country *j*				1.323***
				(0.185)
Geographic distance	−0.017	−0.316***	−0.047	−0.834***
	(0.064)	(0.037)	(0.225)	(0.099)
Frontier	−0.159**	0.024	−0.515**	0.097
	(0.072)	(0.048)	(0.262)	(0.127)
Time difference	0.020*	0.013*	0.071*	0.036**
	(0.012)	(0.007)	(0.041)	(0.018)
Colonial ties	0.027	0.103**	−0.052	0.269**
	(0.068)	(0.045)	(0.242)	(0.121)
Common origin of legal system	0.053	0.077**	0.207	0.197**
	(0.059)	(0.030)	(0.213)	(0.080)
RTA	0.475***	0.069	1.508***	0.190
	(0.109)	(0.054)	(0.364)	(0.142)
BIT	0.067	0.066**	0.308*	0.180**
	(0.047)	(0.027)	(0.169)	(0.071)
Linguistic distance	−0.097***	−0.083***	−0.286***	−0.221***
	(0.027)	(0.017)	(0.094)	(0.045)
Religious distance	−0.092*	−0.124***	−0.385**	−0.313***
	(0.055)	(0.032)	(0.194)	(0.082)
Firm investment in R&D	0.124***			0.144***
	(0.005)			(0.011)
Firm investment in manufacturing		0.035***	0.063***	
		(0.001)	(0.006)	
Sectoral concentration	−0.794***	−0.680***	−3.517***	−3.106***
	(0.063)	(0.036)	(0.220)	(0.085)
ρ	0.215***			
	(0.026)			
Home fixed effect	Yes		Yes	Yes
Host fixed effect	Yes		Yes	Yes
Sector fixed effect	Yes		Yes	Yes
Log likelihood	−36,358		−5125	−32,259
Number of observations	354,768		310,677	354,768

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates for Columns 1 and 2 are coefficients, and for Columns 3 and 4 are marginal effects.

account the possibility of repeated investments, and try and explain the intensive margin of R&D and manufacturing investments. To this end, we use the numbers of projects in R&D and manufacturing that a firm had in a given country over the period 2003-2008 as dependent variables, and estimate the model using negative binomial regressions. The results, reported in Table 12, do not change qualitatively, although the effect of geographic and institutional distance measures is slightly smaller in magnitude. Still, once institutional distance is accounted for, the effect of geographic distance on cross-border R&D investments is not significantly different from zero.

Interdependence between Manufacturing and R&D

So far, we have analyzed investments in R&D and manufacturing as independent events. However, this may not be true, since it is well known that R&D may follow or co-locate with manufacturing plants. For the purpose of this paper, we are not interested in assessing the extent of collocation, nor in how manufacturing activities affect the location of R&D labs. Rather, we are looking at how the interdependence between R&D and manufacturing cross-border investments might change the impact of distance on the probability of setting up R&D labs abroad. To this end, we estimate a bivariate probit model in which the probability of creating an R&D lab abroad is estimated jointly with the probability of setting up a manufacturing plant. In Columns 1 and 2 of Table 13 we report the estimated coefficients.[21] The *p* coefficient suggests that the error terms of the two equations are indeed correlated, so bivariate probit estimates should be preferred. However, for the purpose of our analysis,

Table 14 Robustness test: R&D vs DDT, probit regressions

	R&D	Manufacturing	DDT	R&D	Manufacturing	DDT
Geographic distance	−0.748***	−1.135***	−1.034***	−0.023	−0.883***	−0.567**
	(0.238)	(0.092)	(0.321)	(0.237)	(0.103)	(0.236)
Frontier	−0.268	0.191	0.122	−0.603**	0.058	−0.237
	(0.262)	(0.137)	(0.244)	(0.263)	(0.133)	(0.232)
Time difference	0.061	0.034*	0.131*	0.061	0.035**	0.070
	(0.057)	(0.020)	(0.079)	(0.043)	(0.018)	(0.051)
Colonial ties				0.063	0.286**	−0.088
				(0.247)	(0.126)	(0.234)
Common origin of legal system				0.200	0.215**	0.377**
				(0.215)	(0.085)	(0.174)
RTA				1.658***	0.181	0.424
				(0.401)	(0.148)	(0.382)
BIT				0.255	0.185**	0.014
				(0.172)	(0.074)	(0.157)
Linguistic distance				−0.348***	−0.229***	−0.411***
				(0.096)	(0.047)	(0.101)
Religious distance				−0.334	−0.348***	−0.056
				(0.204)	(0.091)	(0.188)
Firm investment in R&D	0.512***			0.522***		
	(0.024)			(0.025)		
Firm investment in manufacturing		0.100***			0.101***	
		(0.004)			(0.004)	
Firm investment in DDT			0.196***			0.199***
			(0.013)			(0.014)
Sectoral concentration	−3.118***	−1.916***	−3.988***	−3.106***	−1.942***	−3.989***
	(0.252)	(0.103)	(0.211)	(0.253)	(0.103)	(0.212)
Home fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Host fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	−5061	−32,458	−7112	−4999	−31,965	−7026
Number of observations	354,015	403,332	380,190	347,460	396,036	373,520

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates are marginal effects.

the results are qualitatively very similar to the baseline estimates. In particular, it is confirmed that, even allowing for correlation in the error terms, once institutional distance is controlled for, geographic distance is negative and significant only for manufacturing cross-border investments.

A further control along these lines is reported in Column 3 of Table 13, where we introduce, in a standard univariate probit model of the probability of setting up an R&D lab abroad, a dummy that takes the value 1 if a firm has created manufacturing plants abroad over the period 2003-2008. Symmetrically, in Column 4 we control for the R&D investment status in the equation for manufacturing investments. The collocation dummies are indeed very significant,[22] but the effects of the distance-related variables are not significantly affected by the co-location phenomenon.[23]

R&D vs DDT

One of the pillars of our theoretical framework is that the choice set for R&D location is more limited than for other MNEs' value-added activities, and this may leave firms no choice but to locate in a remote location. Indeed, this is true for the more cutting-edge R&D activities, but it may not be true for more routinized tasks. The latter may not need unique competences: thus firms may be able to find a larger number of possible locations where they could off-shore such activities. Under these circumstances, it is likely that MNEs would choose the geographically closer sites, in order to reduce organizational costs. We test for this mechanism by running benchmark regressions in which the dependent variable is equal to 1 if the firm sets up international activities for DDT. The DDT activities are clearly related to the innovation process, but they are closer to the commercialization phase, as opposed to the projects classified as R&D, which tend to be more upstream activities in the innovation process. DDT activities are likely to involve more routinized activities, and do not need as much specialized competences as the one that we label as R&D. Results, reported in Table 14, support this hypothesis. In Columns 1 and 3 it can be seen that the effect of geographic distance is larger (in absolute magnitude) for DDT that it is for R&D, and it is closer to what it is estimated for manufacturing activities. Once institutional distance is controlled for, the effect of geographic separation on DDT reduces dramatically (from -1.034 to -0.567), but remains statistically significant. This suggests that, for DDT also, geographic distance picks up some of the effect of institutional distance, but geographic distance still retains some significant explanatory power.

The Sample of Firms Considered

Another pillar of our theoretical framework relates to the fact that, historically, MNEs have developed technical skills and organizational capabilities that facilitate the transmission of relevant knowledge at a relatively low cost over long distance. To test for this hypothesis more directly we would need firm-level information on the characteristics of the MNEs, such as R&D intensity, the rate of innovation and some measures of organizational complexity, or at least firm age. Unfortunately, such proxies are not available in our data set, but we can provide a rough test of this hypothesis by distinguishing firms according to their home country. In particular, it seems reasonable to assume that firms from Triad countries (Europe, Japan and the United States) have a longer history of internationalization and, on average, they should have developed more advanced technical skills and organizational capabilities. Therefore we submit that for firms from Triad countries the constraining role of geographic distance for cross-border R&D investments should be lower than it is for non-Triad MNCs. The results from Table 15 are in line with this prediction: for

Table 15 Robustness test: Triad vs non-Triad firms, probit regressions

Dependent variable	Sample			
	Non-Triad MNCs		Triad MNCs	
	R&D	Manufacturing	R&D	Manufacturing
Geographic distance	–0.859**	–0.927***	0.104	–0.860***
	(0.390)	(0.158)	(0.315)	(0.148)
Frontier	–0.322	0.078	–0.828**	0.005
	(0.521)	(0.271)	(0.373)	(0.148)
Time difference	0.201**	0.022	0.041	0.023
	(0.095)	(0.030)	(0.057)	(0.025)
Colonial ties	0.615	0.555*	0.023	0.191
	(0.790)	(0.329)	(0.276)	(0.139)
Common origin of legal system	–0.090	0.350***	0.147	0.212*
	(0.392)	(0.128)	(0.288)	(0.112)
RTA	0.824	0.311	1.919***	0.005
	(0.771)	(0.217)	(0.512)	(0.209)
BIT	0.092	0.052	0.265	0.239**
	(0.340)	(0.120)	(0.215)	(0.096)
Linguistic distance	–0.382**	–0.336***	–0.390***	–0.186***
	(0.154)	(0.074)	(0.137)	(0.058)
Religious distance	–0.156	–0.227**	–0.357	–0.396***
	(0.261)	(0.100)	(0.279)	(0.117)
Firm investment in R&D	1.099***		0.440***	
	(0.091)		(0.022)	
Firm investment in manufacturing		0.118***		0.093***
		(0.008)		(0.004)
Sectoral concentration	–1.344	–1.300***	–3.028***	–1.963***
	(0.823)	(0.221)	(0.266)	(0.109)
Home fixed effect	Yes	Yes	Yes	Yes
Host fixed effect	Yes	Yes	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes
Log likelihood	–720	–7873	–4004	–23,489
Number of observations	42,581	97,168	218,212	255,873

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates are marginal effects.

Table 16 Robustness test: Excluding MNEs from the top three source countries (the United States, Germany and Japan), probit regressions

Dependent variable	Sample					
	Excluding US MNEs	Excluding German MNEs	Excluding Japanese MNEs	Excluding US and German MNEs	Excluding US, German and Japanese MNEs	
	R&D	R&D	R&D	R&D	R&D	Manufacturing
Geographic distance	−0.088	−0.207	−0.275	−0.192	−0.445**	−0.666***
	(0.211)	(0.212)	(0.189)	(0.215)	(0.214)	(0.234)
Frontier	−0.397	−0.470*	−0.510**	−0.231	−0.181	−0.135
	(0.254)	(0.251)	(0.222)	(0.285)	(0.269)	(0.299)
Time difference	0.002	0.069*	0.084**	0.014	0.090*	0.060
	(0.041)	(0.037)	(0.036)	(0.042)	(0.047)	(0.046)
Colonial ties	0.158	−0.223	0.103	0.090	0.325	0.377
	(0.286)	(0.220)	(0.210)	(0.293)	(0.270)	(0.290)
Common origin of legal system	0.260	0.036	0.302*	0.110	0.124	0.363*
	(0.183)	(0.190)	(0.169)	(0.192)	(0.185)	(0.193)
RTA	0.973**	1.106***	1.027***	0.885**	0.796*	−0.120
	(0.407)	(0.343)	(0.305)	(0.432)	(0.409)	(0.341)
BIT	0.268	0.175	0.195	0.144	−0.035	−0.287
	(0.165)	(0.169)	(0.166)	(0.182)	(0.193)	(0.179)
Linguistic distance	−0.215**	−0.327***	−0.252***	−0.230**	−0.218**	−0.130
	(0.103)	(0.090)	(0.082)	(0.109)	(0.109)	(0.105)
Religious distance	−0.260	−0.354**	−0.271*	−0.253	−0.156	−0.272*
	(0.167)	(0.168)	(0.144)	(0.162)	(0.156)	(0.159)
Firm investment in R&D	0.330***	0.257***	0.250***	0.380***	0.367***	
	(0.027)	(0.014)	(0.013)	(0.034)	(0.037)	
Firm investment in manufacturing						0.130***
						(0.009)
Sectoral concentration	−0.070	−0.443**	−0.433*	−0.031	−0.012	−2.479***
	(0.270)	(0.218)	(0.222)	(0.319)	(0.370)	(0.355)
Home fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Host fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Sector fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	−2216	−3489	−3479	−1901	−1583	−1786
Number of observations	22,352	37,315	35,831	20,000	15,946	15,931

Note: Standard errors are clustered by home–host-country pairs. *, **, *** denote statistical significance at the 10%, 5%, 1% confidence levels, respectively. Parameter estimates are marginal effects.

non-Triad MNCs geographic distance has a negative and significant effect on both R&D and manufacturing cross-border investments, whereas for Triad MNCs the effect on R&D is non-significant.

A further element of concern may be the high geographic concentration of our sample firms. As illustrated in Table 3, more than 40% of the sample firms are based in the United States, Germany or Japan. One may wonder to what extent these firms drive our results. We check for this in Table 16. In Columns 1, 2 and 3 we exclude firms from the United States, Germany and Japan, respectively. In Column 4 we drop firms from both the United States and Germany, and in Column 5 we exclude all firms from the top three home countries. As shown, excluding firms from any one of the three top source countries does not change the main result we have highlighted in this paper: that is, the effect of geographic distance on cross-country investments in R&D is not significantly different from zero. However, by dropping observations from the whole group of three countries (the United States, Germany and Japan), we obtain a result similar to that in the previous test, wherein all Triad firms were dropped. That is, geographic distance turns out to have a significant negative effect on cross-border R&D investments (Column 5), although still much lower than the effect on manufacturing investments (Column 6). This test further qualifies the consideration we have made of the role of firms from Triad countries in driving our results. Indeed, it appears to be particularly the case for firms originating from some of the most advanced of these countries, which largely determine patterns of FDI localization. Further corroborating our line of argument, it seems even more sensible to assume that firms originating from these three countries - which have accumulated a relatively long multinational experience, and were most involved in FDI projects over the period examined - have developed organizational devices enabling them to transfer knowledge effectively across national borders, largely regardless of geographic distance.

CONCLUSION

One of the most robust findings in the economics and IB literature is that geographic and institutional distance between source and destination markets significantly hinder cross-border economic transactions. However, distance effects have most often been examined with reference to the relatively less value-creating activities, such as manufacturing and sales. Surprisingly, our knowledge of the extent to which distance is also an obstacle for the more value-creating activities, such as R&D, is still limited. This is a crucial question in the IB field, given the increasing importance of R&D activities conducted in competence-creating subsidiaries abroad. Against this background, this paper addresses whether, conditional on internationalizing R&D, firms are subject to the same centripetal/gravitational forces as for less value-creating activities, such as manufacturing. That is, we investigate: (1) whether firms are more likely to set up foreign R&D labs in locations near to the home country (as they tend to do with manufacturing and trading activities); and (2) how important institutional distance factors are in explaining cross-border R&D investments.

Using data on the R&D and manufacturing investment decisions of 6320 firms in 59 countries, we find that, when institutional proximity factors are accounted for, geographic distance does not help explain the location of R&D investments. In other words, it is equally likely that firms will set up R&D facilities in nearby or in more remote locations. By contrast, even controlling for institutional proximity, nearby locations are more likely to be chosen by firms establishing manufacturing plants abroad. In sum, it is precisely cross-border investments that are less value creating where geographic distance matters more. Quite symmetrically, value creation by MNEs comes from activities where the hindering effect of geographic distance can be overcome.

The results are consistent with our interpretative framework, based on a threefold argument. First, the choice of remote locations for R&D labs may be driven by the need to gain access to valuable knowledge that is highly concentrated in a few specialized technology clusters. This may leave MNEs fewer possible location choices, and force them to choose to set up R&D labs in countries relatively far away from their home. Second, MNEs are well placed in the transfer of (codified and tacit) knowledge bits across clusters, and within their own networks of subsidiaries, even over long distances. Third, R&D FDI is particularly affected by institutional distance factors, which heavily influence firms' ability to absorb and transfer knowledge.

It thus appears that institutional connectors - such as the commonality of language, belonging to the same trade area, or sharing similar religious attitudes - help explain bilateral investments in R&D activities more than geographic separation. Indeed, these types of investments may be directed toward remote locations, especially when the extra costs of geographic distance are more than compensated for by the advantages of institutional proximity.

Our results have important normative implications. The most immediate consequence of our analysis is that gaining access to valuable, cutting-edge technology is only the final step in competitive enhancing strategies. Indeed, firms may need to cover long distances to get as close as possible to the key centers of generation of knowledge.

Firms will thus have to make remarkable efforts to monitor centers of excellence all over the world, to select qualified scientists, engineers and managers on a global scale and to organize their international mobility. The complexity of these challenges was clearly perceived by Kuemmerle (1997) in the late 1990s, when he posited that "managers of R&D networks must be global coordinators, not local administrators."

Moreover, our study emphasizes that to attain a global reach in R&D activities, which can be crucial for MNEs' value-creating strategy, the relevant costs are not so much those of traversing physical distance, but rather those of dealing with institutional barriers to effective communication. This has certainly to do with the design, development and improvement over time of organizational routines and structures favoring the circulation of knowledge within the internal networks of MNEs. However, what is perhaps even more important and difficult is to set up effective interfaces with local knowledge sources, which in turn implies the need to get acquainted with (national and corporate) institutional regimes that might be very unfamiliar.

Finally, our work envisages a dynamic process wherein MNEs are key actors increasingly involved in technology transfer from and to countries where valuable knowledge is generated and concentrated. Countries are most likely to gain from being part of this game to the extent to which they can benefit from knowledge spillovers and economic growth. Of course, playing a role in this process and gaining access to relevant knowledge asset is not automatic at all, and implies a commitment by national and regional governments to a wide set of policies. This will necessarily include what Dunning (2009: 27) indicated as "institutional upgrading", focused on the content and quality of innovation systems, of intellectual property rights and more generally aimed at the reduction of institutional distance with respect to key knowledge-sourcing locations.

ACKNOWLEDGEMENTS

The authors thank John Cantwell, Mark Lorenzen, Vasyl Taras, three anonymous reviewers and the Guest Editors (Sjoerd Beugelsdijk and Ram Mudambi) for their helpful comments. This paper also benefited from comments received at various workshops, conferences and seminars, including those held at the Fox School of Business (Temple University, Philadelphia, USA), Henley Business School (University of Reading, UK), Rutgers Business School (Newark, N], USA), UNU-MERIT and School of Economics and Business (Maastricht University, the Netherlands), University of Lausanne (Switzerland) and Nanzan University (Nagoya, Japan). Castellani and Zanfei gratefully acknowledge financial support from the Italian Ministry of University and Research (Prin 2009 project on "Production, R&D and knowledge offshoring: Economic analyses and policy implications"). Jimenez gratefully acknowledges financial support from Caja de Burgos. Research for this paper was partly carried out while Jimenez was a visiting scholar at the University of Perugia, and Castellani was visiting at Rutgers Business School. The authors thank those institutions for their hospitality.

NOTES

[1]Other authors have used similar concepts and denominations, such as asset-exploiting vs asset-seeking FDI (Dunning & Narula, 1995), or home-based exploiting vs home-based augmenting (Kuemmerle, 1997) FDI.

[2]See Beugelsdijk and Frijns (2010), Slangen and Beugelsdijk (2010), Slangen, Beugelsdijk, and Hennart (2011) and Schmitt and Van Biesebroeck (2013) for recent applications of cultural distance to the analysis of exports, affiliate sales, cross-border asset allocation and outsourcing relations.

[3]Some authors claim that distance should be examined in terms of managers' perceptions rather than exogenous differences between countries. Cognitive maps have been used for this purpose (Ellis, 2008; Evans & Mavondo, 2002; Sousa & Bradley, 2006). However, this approach leads to a problem of causality (Dow & Ferencikova, 2010; Dow & Karunaratna, 2006). Since it is unusual to be able to survey a decision maker's perceptions immediately prior to a critical decision, most researchers rely on *ex post* perception. Unfortunately, it is very difficult to distinguish whether *ex ante* perceptions lead to the decision, or whether the *ex post* experience influences the perception itself. Hakanson and Ambos (2010) have analyzed how managers' perceptions are affected by objective measures of cultural, social, economic and institutional, and geographical separation, and found that the latter explain a large share of variance.

[4]Although there are methodological differences in how to measure relevant distance factors, "when one disaggregates the concept of institutional distance, the overlap between psychic distance and institutional distance becomes quite substantial" (Dow & Ferencikova, 2010: 48).

[5]It has been noted that firms locate R&D resources in new geographic areas in order to gain access to "locally embedded sectoral specialists" (Cantwell & Santangelo, 1999: 120), and some of the most productive R&D-intensive firms are co-located near research universities that employ "star scientists" (Zucker, Darby, & Brewer, 1998).

[6]Although it should be noted that foreign production might also be associated with the transfer of some intangible assets, such as patents and designs.

[7]In fact, the costs of transporting material goods across borders impose a relatively stronger limitation on the spatial distribution of supply chains in manufacturing activities. The historical reduction of the cost of moving goods on a global scale, which has been especially dramatic between the second half of the 19th century and the first half of the 20th century (Bairoch, 1990; Dollar, 2001; Findlay & O'Rourke, 2003), is not only affecting some sectors more than others (Hummels & Skiba, 2004), but also appears to have reached a limit over the past two decades. As argued by Levinson (2008: 140): "Slower, costlier and less certain transportation of goods will not put

an end to the growth of international trade. But on the margin, where business decisions are made, the strategies of manufacturers and retailers will change. As transportation eats up a greater share of the total costs of an imported product, supply chains will shorten and production will move closer to home". In sum, the alleged end of a long cycle of falling transportation costs is likely to negatively affect the geographic dispersion of the fragmentation of production and of MNE's manufacturing networks much more than the internationalization of R&D facilities. In a similar vein, Baldwin (2003: 368) suggests that: "As we move on to the second wave of globalization, we presume that the cost of transporting goods asymptotes to some natural limit, but additionally, and importantly, we assume that the cost of trading ideas decreases".

[8]More information is available at http://www fdimarkets.com/.

[9]To clarify what is intended for R&D investments, here are two examples that fDi Markets reports with specific reference to IBM as an investor. Example 1: a nanotech research center in Egypt is intended to be a world-class facility for both local engineers and scientists, and IBM's own researchers, to develop nanotechnology programs. The center will work in coordination with other IBM research efforts in the field in Switzerland and the United States. Example 2: a business solution center to promote new technologies that help save energy used to run computer equipment and reduce hardware management costs. Teaming up with automakers and electronics manufacturers, the center will study how to make the best use of advanced technologies. IBM Japan intends to use the results of these efforts to win system development projects.

[10]One could be tempted to consider DDT as competence exploiting, and R&D as competence creating, but we believe the classification was not designed with this taxonomy in mind.

[11] For the sake of clarity we report only data for EU15- and US-based firms (which account for more than 60% of the sample). The extended table with data on firms from other areas is available upon request.

[12]Since our geographic and institutional differences are mostly time invariant (at least in the short term), there is not much to be gained by estimating our regressions as a panel, so we collapse all the information for investments in the period 2003-2008 into a single data point for each firm-destination country pair.

[13]See http://www.cepii.fr/anglaisgraph/bdd/distances .htm for more details.

[14]The role of BIT as a determinant of FDI has been highlighted in recent studies, such as Egger and Pfaffermayr (2004b) and Egger and Merlo (2007). Data on bilateral investment treaties have been compiled by the authors from information on UNCTAD's website (http://www.unctad.org).

[15]The three components are: (a) the distance between the two closest major religions for each pair of countries (R1); (b) the incidence of country *i's* major religion(s) in country j (R2); and the incidence of country j's major religion(s) in country *i*. More details are provided at https://sites.google.com/site/ ddowresearch/home/scales/religion.

[16]The number of observations may be lower than the theoretical 361,340, owing to missing values for language and religious similarity for Tunisia, and because some countries or sectors have no investments in R&D. In these cases, sector and country dummies perfectly predict these observations, which are thus dropped from the estimation sample.

[17]Results for the individual country and sector dummies have not been shown, but are available from the authors upon request. Suffice it to say that the fixed effects are jointly significant, and a casual inspection of the coefficients reveals that, as expected, the highest destination country fixed effects for R&D investments are found for China, India, the United States, Japan, the major EU countries (such as Germany, France and the United Kingdom) and for some countries in South Asia (Taiwan, Singapore, South Korea and Malaysia). In the case of manufacturing investments, the largest fixed effects are for China, India, Brazil, Mexico, Malaysia, Thailand and Vietnam. As far as the sectors are concerned, we register remarkably higher fixed effects for software and IT, biotech and pharmaceutical for R&D FDI, whereas automotive, beverages and business machines and equipment stand out when manufacturing investments are considered.

[18]ln the next section we perform further robustness tests to ensure that the large number of zeros does not drive our results.

[19]The estimated elasticity implies that, *ceteris paribus,* a country that is 10% further away from the home country has an 11.35% lower probability of receiving manufacturing investments. These estimates are in line with those obtained in gravity models from trade and FDI (De Benedictis & Taglioni, 2011).

[20]Results are available upon request.

[21]We could not obtain marginal effects for bivariate probit regressions, so the magnitude of the coefficients cannot be compared with the baseline probit regressions.

[22]We are aware that endogeneity problems may arise in estimation of the effect of these two variables, and may partially explain their large coefficients. We have

avoided introducing a further complexity in the analysis by estimating our model with instrumental variables, since the purpose of this test is not to evaluate the extent of co-location of R&D and manufacturing, but to assess the robustness of the effect in the distance-related variables.

[23] Ideally, one would like to control for the stock of R&D and manufacturing activities of each firm in a given country. Unfortunately, our data source provides only information on the period 2003-2008, so we do not have any information on the previous activity of our sample firms in the selected countries.

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Accepted by Sjoerd Beugelsdijk and Ram Mudambi, Guest Editors, 7 May 2013. This paper has been with the authors for three revisions.