The contribution of different R&D activities in BRICST to the knowledge creation of OECD regions

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Abstract

- The double diamond model contends that both home and host LAs affect FSAs. Drawing on the view that MNEs act as a link between home and host, and on the idea that host LAs determine the types of incoming R&D activities, we extend this framework and investigate the *indirect* impact of the host on home LAs.
- To this end, by resorting to a sample of 221 regions from 21 OECD countries, the study evaluates the contribution of different R&D activities originating in OECD regions and located in BRICST countries to the knowledge creation of the home investing region.
- Specifically, we test the complementarity between different types of R&D activities in different technology-intensive sectors carried out in BRICST and R&D activities carried out at home to the knowledge-base of the home OECD region from which the investment originated.
- Our findings suggest that R&D activity in emerging countries complements R&D performed in home OECD regions to home knowledge creation when it focuses on *development* in medium technology-intensive sectors and on *adaptation* in knowledge-intensive services. No complementarity is found between any type of R&D activity in BRICST in high technology-intensive sectors and R&D performed in the home OECD regions.

Key Words: overseas R&D activities – host country location advantage - home region knowledge creation - BRICST

JEL codes: F230; O300; O180; R100

Introduction

Multinational enterprises (MNEs) increasingly enter foreign countries to access local capabilities and technological specialisation complementary to their home knowledge (Cantwell 1989). To strengthen their firm-specific advantages (FSAs), MNEs indeed rely on multiple geographical sources of knowledge by tapping into host location-specific advantages (Dunning 1977; Cantwell 1989; Rugman and Verbeke 1993) and benefit from them through reverse knowledge transfer from foreign subsidiaries to the parent (Ambos, Ambos et al. 2006). An extensive body of literature has dealt with the contributions of different types of overseas R&D activities to the MNE's knowledge-related FSAs by distinguishing between home-base exploiting and home-base augmenting (Kuemmerle 1999), and competence-creating and competence exploiting (Cantwell and Mudambi 2005), as well as by proposing more elaborated classifications of overseas R&D activities (e.g. Chiesa 1996; Pearce and Papanastassiou 1999; von Zedtwitz and Gassmann 2002). This stream of research has primarily analysed R&D internationalization from developed markets (DM) to other DM. A first reason is that the growth of overseas R&D laboratories in fast-growing emerging markets (EM) initiated only in the 1990s (Von Zedtwitz 2006) and boomed during the early 2000s (UNCTAD 2005). A second reason is that R&D FDI in fast-growing EM was largely identified as a means to support the growing local market demand and, in this case, little contribution to the knowledge-based FSAs of the whole MNE was expected (Von Zedtwitz 2006). However, the internationalisation of R&D activities by MNEs in EM has recently accelerated and changed facet (UNCTAD 2005). While foreign R&D investments in those countries have traditionally been a means to adapt products or processes to local markets, recent trends suggest that some EM are attracting more high value R&D investments. This change is generally linked to the upgrading of EM and to the increasing globalisation of the world economy (Dunning 1998; Doh 2005).

This new trend of R&D internationalization from DM to EM poses a number of challenges to international business (IB) research. Traditionally, research on international competitiveness has stressed the significance of home location advantages (LAs) in contributing to FSAs as the former are strictly connected to the institutional set-up and spatially-bounded knowledge-flows of the external environment (Porter 1990). IB scholars (Rugman and Verbeke 1993; Rugman 2001) have extended this view and proposed a double diamond model explaining FSAs as a result of both home and host LAs. At the same time, IB and management scholars have recognized that the MNE 'consists of a group of geographically dispersed and goal-disparate organizations that include its headquarters and the different national subsidiaries' (Bartlett and Ghoshal 1990) and which is embedded in (home and host) external networks consisting of all other organizations with which the different units of the multinational must interact. Accordingly, the MNE acts as a link between home and host locations which is able to transfer non-location bound assets from one location to another. In line with this view, we argue that, besides the *direct* effect of home and host LAs to FSAs, the *indirect* effect of host LAs to home LAs should be considered with reference to the internationalization of R&D in EM. The recent technological upgrading of EM (Athreye and Cantwell 2007) calls indeed for an analysis of the opportunities EM may offer to or the threat they may represent for DM LAs. Thus, we focus on the impact of host EM LAs (as perceived by DM MNEs and reflected in their decision of locating in these countries specific types of R&D activities) on DM LAs. The impact is assessed in terms of new knowledge creation. Specifically, we answer recent calls for more IB research at sub-national level (Nachum 2000; Shaver and Flyer 2000) and investigate whether and how different types of R&D activities originating in DM and targeting EM complement R&D performed at home in contributing to home region knowledge creation. To this end, we focus on R&D FDI departing from OECD regions and targeting Brazil, Russia, India, China, Singapore and Taiwan (hereafter BRICST), and on three types of foreign R&D activities (i.e. *research*, *development* and *adaptation*) (Dunning and Narula 1995; Pearce and Papanastassiou 1999).

By resorting to a sample of 221 large OECD regions for which we collected data on patents, socio-economic variables, and R&D investments towards BRICST countries, our findings confirm that R&D investments in BRICST complement the R&D performed in the home investing OECD region in enhancing home region knowledge creation when the overseas R&D laboratory focuses on *development* in medium technology-intensive sectors as a consequence of the technological upgrading of these countries. In addition, we find that the activity of overseas R&D laboratories operating in knowledge-intensive services and focusing on *adaptation* is complementary to home region R&D as a result of the modularity and the high degree of technological learning connected with this activity (Patibandla and Petersen 2002; Athreye 2005). By contrast, OECD laboratories operating in high technology-intensive sectors fail to complement R&D at home to the home region knowledge creation regardless of the type of activity carried out in BRICST, since the technological upgrading of these EM has not yet been fully accomplished (Athreye and Cantwell 2007; Altenburg, Schmitz et al. 2008).

Next section discusses the theoretical framework. Section 3 focuses on LAs and different types of overseas R&D activities. Section 4 develops testable hypotheses. Section 5 presents the data and the sample of analysis, section 6 describes the variables and section 7 the methodology adopted. The exploratory and descriptive analysis and econometric results are presented in section 8 and 9. Concluding remarks are drawn in section 10.

Theoretical framework

MNEs build their competitive advantage on two main elements (Dunning 1977; Rugman and Verbeke 1992): FSAs and LAs. FSAs are the proprietary know-how, capabilities to coordinate activities across-borders and the firm's knowledge base. The LAs are the benefits associated with the localisation of certain activities in particular countries or regions. Extant research converges on the idea that home LAs are a major source of international competitiveness (Dunning 1977; Porter 1990; Rugman 2001; Kuemmerle 2005). Nonetheless, debate has been ongoing whether firm's international competitiveness may be solely grounded in its home country as in Porter's (1990) diamond model and in traditional theories of MNEs (Vernon 1966; Hymer 1968), or foreign input markets for valuable resources and/or foreign output markets for delivery of end products do contribute to corporate international competitiveness (Dunning 1977; Rugman 2001; Kuemmerle 2005) as suggested in Rugman and Verbeke double diamond framework (Rugman and Verbeke 1993) and in contributions that observe that subsidiaries in the host location can play a role to sustain and improve the competitive position of the MNEs (Bartlett and Ghoshal 1989; Birkinshaw and Hood 1998; Gupta and Govindarajan 2000; Rugman and Verbeke 2001).

With respect to R&D internationalization, IB research has embraced this later view (Cantwell 1989). In particular, it has been argued that foreign R&D investments are motivated by the need to build upon and extent the extant core competences of the MNEs or to access to complementary assets that are lacking at home. In this perspective, MNEs are becoming a multi-hub ‘integrated network’ in which each unit contributes to the creation of new knowledge by relying on the host-country knowledge (Ghoshal and Nohria 1997; Criscuolo and Narula 2007). The implications of this reasoning are that both host and home locations of R&D activity can potentially enhance FSAs as in the double diamond framework. Specifically, empirical evidence focusing on sub-national locations shows that there is a link between the technological capacities of the home region and the innovativeness of the MNEs that have their headquarters in the region (see e.g. Cantwell and Iammarino 2003). Similarly, evidence is available on the contribution of foreign R&D units to the creation of new technological competences at home through the leveraging of host-location specific knowledge assets (Gassmann and Von Zedtwitz 1999; Criscuolo and Narula 2007).

The implicit view of the MNE underlying this argument is that of an inter-organization network including both headquarters and different subsidiaries which are embedded in an external network of customers, suppliers, regulators and competitors with which they must interact (Bartlett and Ghoshal 1990). In particular, headquarters embeddedness at home enables to build the home base of the MNE international competitiveness by drawing on the home country-specific diamond factors. Similarly, foreign subsidiaries embeddedness in host locations enables the entire network to benefit from host country-specific diamond factors. Therefore, besides the *direct* contribution of home and host LAs to FSAs, the *indirect* contribution of host LAs to home LAs needs to be considered within the present trend of growing R&D internationalization which has increasingly involved new players as the BRICST countries. This argument can be summarized in Figure 1 where the *direct* effects of home and host LAs on FSAs are illustrated by the straight lines and the *indirect* effects of host on home LAs are illustrated by the dotted lines. For the sake of completeness, Figure 1 also reports the *indirect* effects of home on host LAs. However, we will not enter into their discussion as these effects have been widely explored by the literature on inward FDI and spillovers (e.g. Blomström and Kokko 1998; Smarzynska Javorick 2004).

[Figure 1 just about here]

LAs and overseas R&D activities

Many factors in the host location may affect the home-base knowledge of investing MNEs and, as a consequence, the MNE home LAs. In particular, the level of development of the host location, the availability of host specialised knowledge, the host supply of technical and research-base labour, the possibility to establish linkages with public research centres are factors that contribute to the host LAs and attract specific activities by foreign investors. These factors can then affect *directly* the overall FSAs by means of reverse knowledge transfer from subsidiary to parent (Mansfield 1984) and *indirectly* the home LAs as a result of the MNE embeddedness in its home market (Forsgren, Holm et al. 2005).

As far as R&D internationalization is concerned, extant research has documented that the type of LAs that the host location can offer determine the types of incoming R&D activities (Pearce 1999). That is, the different types of foreign R&D activities located in the host location revealed the perception of the host LAs by the foreign investor. Highly innovative locations attract mainly foreign-R&D laboratories that augment home-base knowledge (Pearce 1989; Florida 1997; Kuemmerle 1999; Cantwell and Mudambi 2005) and less technological dynamic locations attract R&D laboratories exploiting home-base knowledge (Dunning and Narula 1995). In host markets primarily offering LAs related to the domestic demand potentials, foreign R&D activity has traditionally taken the form of technical support to local production for minor product or process adaptation. Being this type of R&D primarily market-driven, laboratories carrying out adaptation R&D type of activities exploit the home-base knowledge (Ronstadt 1977; Hood and Young 1982; Dunning and Narula 1995). With reference to the Triad countries, Pearce and Singh (1992) show that this type of activity is performed on a regular basis by a large share of foreign R&D laboratories and Pearce and Papanastassiou (1999) document that it is mainly performed by laboratories with a strong local mandate. In host markets primarily offering location advantages related to local skills and expertises (e.g. applied scientists, technicians, engineers) (Dunning 1993), and opportunities to exploit economies of scale in R&D and market demand (Enright 2009), foreign R&D activity has traditionally involved development of entirely new commercial products, and/or of specific products and/or process characteristics. This type of R&D activity has been mainly located in overseas R&D in advanced countries (Pearce and Singh 1992; Pearce and Papanastassiou 1999) and has been traditionally undertaken by both laboratories with local mandate and laboratories that are more oriented toward the global R&D activities of the MNE (Pearce and Singh 1992). In host markets offering location advantages related to the acquisition of new complementary local knowledge and/or to the monitoring of local scientific knowledge (Florida 1997), foreign R&D activity is oriented towards research aiming at augmenting the exiting home-base knowledge and eventually to create a possible commercial application of the research outcome, which can be exploited by the whole multinational network (Pearce and Papanastassiou 1999). Due to its strategic role, this type of R&D activity is likely to be located close to the parent company. However, the MNE may decide to undertake research activity in foreign locations where it can benefit from knowledge spillovers from other firms, universities or research institutes. Traditionally, these laboratories have been located in innovative clusters and technological dynamic regions located in DM (Cantwell and Janne 1999; Iammarino 2005).

As far as the home location is concerned, following a call in IB for more research at sub-national level (Nachum 2000; Shaver and Flyer 2000) we focus on sub-national regions as home location and investigate the effects of OECD R&D activity in BRICST on the sub-national OECD region from which the investment initially departed. The reason for our unit of analysis at home is threefold. First, firms are primarily embedded in their home local contexts where trust-based relationships ease knowledge transmission and learning (Lam 1997) and, in particular, the local diffusion of new foreign knowledge in the home market. Second, the innovation literature has largely reported on the local nature of learning and knowledge spillovers (Jaffe, Trajtenberg et al. 1993; Florida 1995). Along these lines, the regional system of innovation (RSI) approach has taken the sub-national entities as valuable units of observation to describe the spatially-bounded factors that influence the innovation of local firms (Cooke 2005). The RSI approach is based on the idea that both geographically and institutionally localised factors have an effect on the innovation outcomes of local actors whose interactions are affected by rules, norms or shared values that emerged in the region, as well as the administrative and legal set-up that are strongly region-specific (Freeman 1987; Lundvall 1992; Cooke, Uranga et al. 1997). Third, greater differences in knowledge creation are documented across regions within and across counties in DM (for an analysis of the European case see e.g. Caniëls 2000).

As emerges from the above discussion, extant literature has primarily examine the geographical configuration of different types of R&D activities by MNEs almost exclusively with reference to DM, where the technological advanced regions are located. However, more recently EM and - in particular - BRICST have received the majority of foreign R&D investments (UNCTAD 2005; Belderbos and Sleuwaegen 2007). Therefore, in what follows, we develop testable hypotheses on the contribution of different R&D laboratories originating from OECD countries and located in BRICST to the knowledge creation at home.

Hypothesis development

Foreign R&D laboratories established in the 1990s in South-East Asia, China and Eastern Europe were initially driven by the new market-opportunities and therefore primarily focused on adaptation

(Von Zedtwitz 2006). More recently, the dramatic growth of R&D FDI in these countries has been related to the improved local conditions, the rise of local innovative clusters, investments in infrastructures and availability of local talents (Bardhan and Jaffee 2005). Extant research has pointed out that MNEs are increasingly locating innovative activities in EM to access skilled workers at lower cost as well as that R&D activities in those countries are not exclusively motivated by the technical support to the local production, but progressively by opportunities to source local knowledge and technology (Dossani and Kenney 2003; Doh 2005; Manning, Massini et al. 2008). Thus, the growing number of R&D inward FDI in EM during the early 2000s (UNCTAD 2005) makes wonder whether foreign R&D laboratories have evolved towards a more strategic role as a result of the evolution of host LAs, as also suggested by the rise of EM MNEs (Sauvant 2008). Empirical evidence documents indeed that EM have undertaken a process of technological upgrading and have now entered into a phase of imitation and replication of foreign technologies, being ultimately able to originally produce new knowledge (Athreye and Cantwell 2007).

However, the effect of different types of foreign R&D activities in BRICST on home regional knowledge creation is likely to vary depending on the technological intensity of the sector of operation of the overseas R&D laboratory. Extant research has documented that EM have been able to attain the required level of capacities and technological autonomy in order to specialise narrowly and produce new technologies along the global value chain (Humphrey and Schmitz 2000; Athreye and Cantwell 2007). This process of technological development may follow some stages as EM operate first in the more mature technologies, and only later in new emerging technologies, although some exceptions might be detected (Jin and Von Zedtwitz 2008). In particular, BRICST countries tend to be specialised in medium technology-intensive sectors, for which they can benefit from (skilled) labour intensity and resource-based advantages (Nolan 2004; Von Zedtwitz 2006). We therefore expect that OECD R&D laboratories operating in medium-technology intensive sectors are capable to contribute to home region knowledge creation when they focus on development due to the current phases of the technology-upgrading of BRICST. By contrast, we expect that OECD R&D laboratories in BRICST operating in high technology-intensive sectors are not capable of contributing to home region knowledge when carrying out locally in research nor in development since they have not moved up to this level of technological maturity as yet (Athreye and Cantwell 2007; Altenburg, Schmitz et al. 2008). In addition, in both types of technology-intensive sectors we do not expect any contribution to home-region knowledge-creation from OECD laboratories focusing on adaptation as this R&D activity (at least in manufacturing) is traditionally devoted to technical support for local production without any original knowledge creation. Accordingly, we posit

> **Hypothesis 1**: OECD R&D laboratories in BRICST operating in medium technology-intensive sectors and carrying out locally development complement R&D performed at home in the knowledge creation of the home region.
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> **Hypothesis 2**: Regardless of the type of activity carried out locally, OECD R&D laboratories in BRICST operating in high technology-intensive sectors do not complement R&D performed at home in the knowledge creation of the home region.

A specific feature of knowledge-intensive service (such as IT services and software) is that they require high skills, strong educational institutions and ICT infrastructures (Manning, Massini & Lewin, 2008). This explains the rise of IT services and software offshoring and outsourcing, for example, in India and China (Lewin & Peeters, 2006) where skilled workers are locally available at relative low costs and governments have designed effective industrial policies (Arora, Arunachalam et al. 2001; Patibandla and Petersen 2002; Ernst 2006; Bunyaratavej, Hahn et al. 2007). In particular, EM have been recognized as major recipients of R&D investments in knowledge-intensive services, especially India (and more recently China) in the software industry (UNCTAD 2005). Being driven by domestic export-oriented firms, the Indian software industry has been mainly engaged in customised software services, which constitute the lower value activities of the industry (Athreye 2005). Chinese software industry is still embryonic and during the early 2000s Chinese top software companies exhibited weak capabilities, both in the organizational attainments and in the international quality standard of their products (Tschang and Xue 2005). Thus, Chinese software industry has been dominated by foreign multinationals that have mainly engage in software customisation (Tschang and Xue 2005). Therefore, despite the long experience of Indian software, India mainly operates in the lower end of the value chain, and the early stage of development of Chinese software industry makes China specialised in the most standardised and low-skilled tasks of the value chain. As consequence, the exploitation of host LAs by foreign R&D laboratories mainly occurs in the lower-end of the R&D activities, namely in the adaptation phase. In these specific sectors, the focus of overseas laboratories on adaptation can contribute to home LAs. While in high and medium technology-intensive sectors adaptation would hardly create knowledge that could effectively contribute to home knowledge creation, in the case of knowledge-intensive service sectors, the modularity and the high degree of technological learning connected with software products (Patibandla and Petersen 2002; Athreye 2005) facilitate the contribution to home knowledge creation of overseas laboratories locally carrying out adaptation. Indeed, the nature of the production activities of these sectors makes easier technological learning, which is not often the case in other manufacturing activities (Patibandla and Petersen 2002). In other words, IT engineers and technicians in the overseas laboratory may find out improvements or new ideas that can be easily communicated at home while adapting extant services products to local market. By contrast, higher value activities in knowledge-intensive services sectors are locally less developed and, as a result, this limits the contribution of overseas laboratories focusing on research and/or development to home country knowledge creation (Athreye 2005; Tschang and Xue 2005).

> **Hypothesis 3:** OECD R&D laboratories in BRICST operating in knowledge–intensive service sectors and carrying out locally R&D adaptation activities complement R&D performed at home in the knowledge creation of the home region.

Data

The empirical analysis is based on a dataset built from three main sources: the OECD REGPAT database (version January 2010), fDi Market database, and the OECD Regional Database (RDB).

The OECD REGPAT database collects patent applications filed according to the Patent Cooperation Treaty (PCT) procedure and designating the European Patent Office (EPO) for the final grant. The PCT procedure gives the possibility to apply for patent rights in many countries by filing a single international application in a single patent office (Maraut, Dernis et al. 2008). The main advantages of the OECD REGPAT database are twofold. First, it reduces possible domestic bias. EPO is generally considered non-bias toward a particular nation (Le Bas and Sierra 2002). In addition to that, PCT procedure is a standardised international procedure that is less likely to suffer from domestic bias of national (e.g. USPTO) or regional patent offices. Lately, PCT applications have grown substantially and it has been observed that European and US applicants contribute equally to this increase, thus confirming that the PCT procedure with EPO designation is not bias towards US or EU firms (Khan and Dernis 2006). The second main advantage of OECD REGPAT is that the patents have been regionalised by linking each application to regions according to the addresses of the applicant and inventor. The regional divisions are based on the Territorial Grids by OECD (2008). The OECD grids use two hierarchical levels: Territorial Level 2 (TL2), which is the more aggregated level, and Territorial Level 3 (TL3). In addition, in REGPAT each patent is assigned to one or more International Patent Classification (IPC, version 8th) codes, which we have classified following the organisation of the IPC codes based on the technological areas (Schmoch 2008; WIPO 2008). In particular, all IPC codes are grouped into 35 fields of technologies and then aggregated into 5 groups of technologies which are defined as Electrical Engineering (*EE*), Instruments (*I*), Chemistry (*C*), Mechanical Engineering (*ME*), and Other fields (*O*) (see WIPO 2008 for a detailed description).

The information on R&D laboratories in BRICST are drawn from the fDi Market database, which collects detailed information on cross-border greenfield and brownfield investments worldwide since 2003 based upon media sources and company data. For each investment, fDi Market reports information on the investment (such as the industry sector of the investment), name of the parent company (whose industry sector may differ from the one of the investment) and the location of both the parent company and the local unit. Moreover, the database also provides a description of the activity carried out by the local unit. For the sake of this study, we classified each OECD R&D laboratory in BRICST depending on the type of research activity (k) undertaken and the technological-intensity of the sector of operation (z). As far as the type of research activity is concerned, we identified three categories following previous studies (Ronstadt 1977; Hood and Young 1982; Pearce and Singh 1992; Dunning 1993; Pearce and Papanastassiou 1999). Specifically, by means of a keyword search on the description of the investment provided by the database we identified first R&D laboratories locally carrying out *research* (R) activity broadly defined as "basic", "scientific", "fundamental", "frontier technology" research, and application of such research into general fields that are potentially relevant for the activity of the MNE. In this category, we also included the activities of "hub", "centre of excellence", or part of a "global" network of R&D centres, as these laboratories perform mainly basic and applied research as part of integrated cross-border R&D activity (Hood and Young 1982; Pearce and Papanastassiou 1999). Second, we identified R&D laboratories locally carrying out *development* (D) activity that refers to "development" and "solutions" of identifiable products or processes for product commercialisation or engineering-detailed processes. Finally, we indentified R&D laboratories carrying out locally product and process *adaptation* (A) which include the R&D laboratories that apply current products or technologies to the local "customer needs". We also included in this category the R&D laboratory that "supports" local sales and marketing activities, and provides "technical services".

As far as the sectoral classification is concerned, we converted the SIC sectors provided by fDi Market into the OECD technological-intensive sectors of economic activities (Hatzichronoglou 1997): low, medium-low, medium-high, and high technology-intensive sectors. Due to very low number of observations in the former two categories, we aggregated the R&D laboratories in low, medium-low, and medium-high technology intensive sectors in one single sector, which we named medium technology-intensive. In addition, we relied on the EUROSTAT (2006) classification to classify the investments in services. Table A.1 column 1 lists the fDi Market sectors, column 2 reports the relative OECD and EUROSTAT sectors and column 3 the three sectoral aggregations adopted in our analysis (i.e., medium (*m*), high *(h*) and knowledge-intensive services (*ks*)).

[Table A.1 just about here]

Finally, the OECD RDB provides data on the R&D expenditures of OECD regions, as well as other socio-economic indicators (e.g. demographic statistics, GDP and labour market indicators). In addition to these sources, we resort to the UNCTAD FDI database.

Our sample consists of 221 TL2 regions of 21 OECD member countries[i] from which R&D investments departed to BRICST over the period 2003-2005. For the majority of the European Union countries, the Territorial Levels are equivalent to the NUTS Eurostat Classification[ii].

Variables

Dependent variable

Our dependent variable is a proxy for the knowledge creation (Griliches 1990; Jaffe, Trajtenberg et al. 1993) of the region in which the parent company establishing an R&D laboratory in BRICST is located. We measured knowledge creation as the fractional count of PCT patent applications aggregated by the region *i* of residence of the inventor in the years 2006-2007 (2-year average), transformed in logarithm (*logHOMEKC*) to ensure the normality of the distribution. It is worth noting that none of the OECD regions in the sample records zero patents. When multiple inventors participate to the patent, the patent is equally shared among them. Therefore, for each region the dependent variable is the sum of the patent shares of the inventors resident in that region.

Independent variables

The independent variables are the 3-year average R&D expenditures in region *i* ($RDhome_i$), and 3-year sum of the number of R&D investments in BRICST in the technological-intensive sector *z* (with *z* equals *m*, *h*, or *ks*) and in the innovative activity *k* (with *k* equals *R*, *D*, or *A*) made by MNEs whose parent company is located in region *i* ($RDhost_{izk}$).

Controls

At the level of the region, many characteristics affect the innovation outcome of the local firms. We want to control for locally-bounded features of the home region by relying on the literature on RSI (Freeman 1987; Lundvall 1992; Cooke, Uranga et al. 1997). According to this theoretical stream, sub-national units exhibit idiosyncratic characteristics such as inter-firm relationships, role of public sector, institutional set-up of the financial sector, R&D organisation, and the role of education and training (Freeman 1987; Lundvall 1992).

To proxy for the strength of the *inter-firm relationship*, we assumed that in agglomerations firms have more possibilities and occasions to interact, as for examples in cities (Feldman and Audretsch 1999) or clusters (Porter 1990). As customary in the literature (e.g. Crescenzi, Rodriguez-Pose et al. 2007; Sterlacchini 2008), we used the population density to proxy for the level of local agglomeration (*INTERFIRM*). To control for the *role of public sector*, we used a dummy to account for the region in which the capital city is located because in that region is very likely to find government research centres with large intramural R&D facilities from which considerable knowledge spillovers might arise. For this reason, we introduced the variable *PUBLIC SECTOR* that takes value 1 for regions with the country capital city (Feldman 2003). We accounted for the *role of the financial sector* with the share of employment in financial intermediation (*FINANCIAL SECTOR*) which indicates the relative importance of the financial sector in the region and, as consequence, the closeness of the financial institutions to the local economy. The relationship between innovative firms and funding (e.g. venture capital, public funding, private banks, etc.) is well known, therefore the more localised are the financial institutions, the closest they are to the needs of innovators (Cooke, Uranga et al. 1997). Another element of the innovation system highlighted in Lundvall (1992) is the significance of the *R&D organisation*. Specifically, firms are moving away from an innovative process that exclusively relies on internal R&D resources towards a more ‘open’ R&D activity (Chesbrough 2003) in which new ideas comes from inter-firm collaborations, triple-helix relations (Etzkowitz and Leydesdorff 2000), collaborations with start-ups and scientists' networks (Colombo, Grilli et al. 2006). Given the rise of international technological collaborations (e.g. Hagedoorn and Duysters 2002), we controlled for the degree of openness of the RSI in the R&D organisation by a variable (*OPENNESS*) that measures the share of patents with multiple inventors where at least one inventor is located in another country. We also controlled for the *role of education and training* as discussed in Freeman (Freeman 1987) by using the share of population with tertiary level of education (*EDUCATION*).

As the regions vary in dimension (both geographically and in the number of inhabitants), we controlled for the population (*POPULATION*), given that the OECD classification is based on existent administrative divisions. Moreover, to take into account the participation of the region in the global flows of FDI, we controlled for the attractiveness of the country by introducing the net value of FDI inward stock calculated as difference between FDI inward stock and FDI outward stock, based on the UNCTAD database (UNCTAD 2008). Positive value of this variable indicates that the country attracts more FDI than the ones flowing out. We built a binary variable taking value 1 for countries with positive balance, 0 otherwise (*ATTRACTIVENESS*).

We also wanted to control for the different regional propensity to patent (*PATENT PROPENSITY*) across technologies (Scherer 1983). By relying on the patent field classification at the 5-group level, we then calculated the revealed technological advantage (RTA) index as follows:

$$RTA_{ij} = \frac{P_{ij}/\sum_j P_{ij}}{\sum_i P_{ij}/\sum_{ij} P_{ij}} \tag{1}$$

where P_{ij} is the number of patents in region i in technological group j, with j equals *EE*, *I*, *C*, *ME* or *O* as defined above. Thus, the index gives the share of the patents of the region i in the technological group j (numerator), weighted by the share of the patents of all regions in the technological group j on total patents of the sample (denominator). As the index takes the values between 0 and $+\infty$, we normalise it to compel its variation between −1 and +1

$$adjRTA_{ij} = \frac{RTA_{ij}-1}{RTA_{ij}+1} \tag{2}$$

Values close to +1 (-1) indicate a comparative technological advantage (disadvantage) of region *i* in the technological group *j*.

To control for the size of the R&D offshoring activities departing from the OECD regions, we used the total value of R&D offshoring investments in the technological sector *z* in the activity *k* ($VALUE_{zk}$). Finally, a set of controls for the host countries by technological sectors were included to account for the sector-specific idiosyncrasies of the emerging economies considered, which might affect FDI location choice (e.g., the Intellectual Property Right system, see Lall 2003) and MNEs' technological strategies (Zhao 2006). We also controlled for home country effects by including in the model two dummies for North American (*NORTHAMERICA*) and Western European regions (*WESTEUROPE*). All the controls variables refer to the period 2003-2005. Table 1 shows the descriptive statistics and correlation matrix for the continuous variables used in the analysis.

[Table 1 just about here]

Methodology

Complementarity

We want to test whether the R&D performed in the home OECD region and the R&D activities of OECD laboratories in BRICST are complements in the home creation of knowledge of the investing region. The complementarity between any two elements (being any activities of firms, regions, or industry) means that doing more of one element increases the payoff of doing the other element.

Following Giuri, Torrisi and Zinovyeva (2008) and Cassiman and Veugelers (2006), we applied the productivity approach to complementarity and transformed our independent key variables (i.e. $RDhome_i$ and $RDhost_{izk}$) into dummies. The reason for choosing to work with dummy rather than continuous variables primarily relies on the skewness of the variable $RDhost_{izk}$, making meaningless any continuous measure. *HOME* takes the value of 1 if $RDhome_i$ is greater than regions' mean. Given the sector of the local laboratory (i.e. *m*, *h*, *ks*) and the types of research activity (i.e. *R*, *D*, *A*), we created nine dummy variables $HOST_{zk}$, which result from the combinations of the three *z* technological sectors and three *k* types of R&D activities. For each OECD regions, we computed the average number of investments in each of the nine *zk* combinations of investments departing from the region in question. For each region *i*, we then assigned value 1 to $HOST_{zk}$ if the number of the *zk*-investments is higher than the average number of *zk*-investments departing from all OECD regions. Then, we created all possible combinations between *HOME* and the $HOST_{zk}$ variables. Specifically, $HOMEHOST_{zk}$ equals 1 if *HOME* equals 1 and the relevant $HOST_{zk}$ variables equal 1, and $ONLYHOST_{zk}$ equals 1 if *HOME* equals 0 and the relevant $HOST_{zk}$ variables equal 1. Therefore, we ended up with nine pairs of categories to be used in nine different specifications of our model. *ONLYHOME* (that equals 1 if *HOME* equals 1 and $HOST_{zk}$ equals 0) and *NOHOMEOFF* (that equals 1 if *HOME* and $HOST_{zk}$ equal 0) remain the same across specifications.

The model

To test our hypotheses, we estimated a maximum likelihood *Spatial Lag model* (Anselin 1988), where the knowledge creation in the investing home OECD region at time *t* ($logHOMEKC_{it}$) is estimated as a function of a vector of the combinations of R&D activities C_{cit-1} and a set of controls X_{it-1} at time *t*-1. Specifically, we estimated:

$$logHOMEKC_{it} = C_{cit-1}\theta + X_{it-1}\beta + \rho WHOMEKC_{it} + \varepsilon_i \qquad (3)$$

where the subscript *c* refers to the nine pairs of combinations of $HOMEHOST_{zk}$ and $ONLYHOST_{zk}$, and to the variables *ONLYHOME* and *NOHOMEOFF*. The spatially lagged dependent variable $WlogHOMEKC_{it}$ is used to account for the spatial autocorrelation that might arise when dealing with cross-sectional data of geographically close units of observations (Acs, Anselin et al. 2002; Moreno, Paci et al. 2005). In particular, we decided to insert it after testing for the presence of spatial dependence in our data by means of Moran'I test with a binary contiguity matrix (*W*). Such $N\times N$ matrix (where *N* is the number of regions) takes the value 1 when the pair of regions share a border or are separated by few kilometres of sea- or lake-water (e.g. the US and the Canadian states along the Great Lakes area), 0 otherwise. As the Moran'I test detected spatial autocorrelation, we followed the standard spatial econometric literature for the lag model (Anselin

1988) and included in the model the dependent variables 'weighted' by the spatial weight matrix W ($WlogHOMEKC_{it}$) which controls for the patenting activity of neighbouring regions. The positive and significant coefficient ρ means that the patenting of the regions i depends on the patenting of its neighbours.

The test of complementarity is a Wald test based on the following constraint:

$$\theta_{11} - \theta_{10} \geq \theta_{01} - \theta_{00} \tag{4}$$

where the first subscript refers to *HOME* and the second to $HOST_{zk}$. Therefore, the coefficient θ_{11} belongs to $HOMEHOST_{zk}$, θ_{10} to *ONLYHOME*, θ_{01} to $ONLYHOST_{zk}$, and θ_{00} to *NOHOMEHOST*. The rejection of the equality hypothesis implies the complementarity between *HOME* and $HOST_{zk}$.

Exploratory/Descriptive analysis

As first exploratory step to search for complementarity, we looked at the unconditional correlation between the complements *HOME* and the different $HOST_{zk}$ combinations. Table 2 (column 1) shows the pair-wise correlations tests between *HOME*, on the one hand, and $HOST_{zk}$ variables, on the other hand. All the correlations are positive and significant, already suggesting complementarity (Cassiman and Veugelers 2006). Across industries, the $HOST_{zk}$ in high technology-intensive sectors ($HOST_{Rh}$, $HOST_{Dh}$, $HOST_{Ah}$) have the highest correlation with *HOME*. In column 2, Table 2 also reports the number of regions falling in each category.

[Table 2 just about here]

Figure 2, 3 and 4 show the number of R&D offshoring investments hosted by each of the BRICST countries in the technological sector *z* in the type of research activity *k*. In all sectors, China and India receive the majority of investments. In addition, within each of the three sectors, almost every country receives more *D* investments than *R* or *A*. As far as R&D investments in medium technology-intensive sectors are concerned (Figure 2), for all BRICST countries the bulk of investments concerns *R* and *D* types of research activities, except for Taiwan (that does not record any R&D investments in this sector) and Brazil (that hosts investments in all but in *D*). China receives the largest number of investments, especially in *D* and in *A*.

[Figure 2 just about here]

In high technology-intensive sectors (Figure 3), the majority of investments concerns *D* type of research activities with the exception of Russia. China is again the most important recipient country in *D*, followed by India. The number of investments received by Taiwan and Singapore is also remarkable. In particular, Singapore receives almost as much in *R* as in *D*.

[Figure 3 just about here]

Figure 4 shows the distribution of the number of the R&D investments for knowledge-intensive services sectors in BRICST. India is receiving the highest number of R&D offshoring investments, especially in *D*. China is the second most important destination. The amount received by the other countries is negligible, thus being in line with the literature about the relevance of Indian software industry and the more recent surge of China's software industry (Athreye 2005; Tschang and Xue 2005).

[Figure 4 just about here]

Results and discussions

Table 3 shows the econometric results by type of research activities and sectors. In all models, the variable *NOHOMEOFF* has been dropped due to collinearity with the other three combinative categories.[iii] In Table 3, columns under the heading "Model 1" reports the results for the medium technology-intensive sector. The variable *ONLYHOME* is positive and significant in all three specifications, which means that the regions doing only R&D at home on average increase their knowledge creation. In *A*, $ONLYHOST_{zk}$ is significant and negative, indicating that when OECD regions carry out only R&D abroad in the *A* type of research activity, their knowledge creation at home decreases. When we check for the additional contribution of doing both R&D at home and R&D in BRICST, the Wald test on the equality constraint is rejected for only *D* ($p \leq 0.05$), hence showing complementarity between R&D at home and overseas R&D in *D* in medium technology-intensive sectors (H1). This means that the joint situations of above-average R&D in the OECD regions and above-average overseas activity in BRICST in *D* in those sectors give a higher payoff than doing either of the two R&D activities in isolation.

[Table 3 just about here]

The columns of “Model 2” reports the results for high technology-intensive sectors. As for previous specifications, the variable *ONLYHOME* is always positive and significant. No significance is found for neither of the other combinations. The complementarity tests fails for all the three types of R&D activities, thus confirming the lack of additional contributions by laboratories located in BRICST to the knowledge creation at home in high-technology intensive sectors (H2). That is, R&D laboratories in BRICST do not increase the marginal return of home knowledge creation in the case of high-technology intensive sectors regardless of the type of research activity carried out.

“Model 3” columns provide the results for the knowledge-intensive services sectors. As for previous specifications, the variable *ONLYHOME* is always positive and significant. In *A*, $ONLYHOST_{zk}$ is positive and significant, showing that in these sectors the market-driven R&D laboratories positively affect the knowledge production at home. The complementarity is found only as far as *A* is concerned ($p \leq 0.10$), thus supporting H3. Due to the specialisation of BRICST, and especially India and China, in such sectors the modularity of services and the high technological learning embodied even in the simplest adaptation phase, the OECD laboratories in BRICST locally carrying out *A* increase the marginal returns of knowledge creation in OECD regions.

Conclusion and implications

By challenging the view that the location of R&D laboratories in EM is mainly motivated by adaptation to local markets with little or no reverse transfer of knowledge to the home-base, this study suggests that BRICST countries may play a role in the knowledge creation of investing DM as a result of their advancement towards more autonomous production of new technologies, investments in human capital, rise of innovative clusters. Specifically, we assess the complementarities between the overseas R&D activities located in BRICST and R&D activity performed at home to the knowledge creation of the OECD investing home region. To this end, we qualify our analysis with reference to the technological intensity of the sectors in which the R&D laboratory operates and the type of R&D activity carried out locally. In medium technology-intensive sectors the activity of overseas laboratories carrying out *D* is complementary to the R&D performed at home as a result of the technological upgrading of BRICST which have developed idiosyncratic capabilities appealing to DM MNE. By contrast, no complementarity is detected when the overseas laboratory operates in high technology-intensive sectors regardless of the type of innovative activity performed. Complementarity is also found between home region R&D and overseas R&D activity when the OECD laboratory operates in knowledge-intensive sectors and focuses on *A*, where BRICST countries show strong LAs.

The study offers three contributions to IB research. First, it extends the double diamond framework by suggesting an *indirect* effect of host on home location as the MNE acts as a link between its home and host network of embedded relationships. Second, it enriches the literature on the effects of FDI, which has largely explored the impact of inward FDI in the host market and, as far as the impact at home is concerned, the focus has primarily been on the direct effects of overseas subsidiaries on the parent company. By contrast, our knowledge on the impact on the home region where the parent is embedded is scant. A final contribution is closely related to the IB literature on EM, which has investigated the determinants of inward FDI from DM to EM (Ramamurti 2004; Bunyaratavej, Hahn et al. 2007; Lewin, Massini et al. 2009) and the impact of outward FDI from EM on host DM (e.g. see Sauvant 2008), but, as far as our knowledge is concerned, an analysis of the impact of inward FDI from DM to EM on home DM is lacking, despite its relevance also for policy-making related issues.

The study provides indeed important policy implications as to whether DM governments should favour or discourage FDI into EM. Governments from developed countries need indeed clear guidelines on whether and how to design outward FDI policies and on their expected impact at home. The study has also significant managerial implications. Debate is ongoing on the threats or opportunities these new players may offer to established technological leaders in DM. Thus, managers need to be aware of the gains and losses that investments in BRICST may bring about. Our findings may be useful in both respects as they neatly call for sector-specific and activity-specific policies and corporate strategies.

The study suffers from a number of limitations. First, we are not able to distinguish greenfield from brownfield investments and we fail to account for other types of entry modes into EM such as merger and acquisitions and joint ventures. However, greenfields tend to be the most common entry mode to establish R&D facilities abroad in EM (UNCTAD 2005). Second, our data does not allow us to have more precise information on the roles of overseas subsidiaries within the internal MNE’s network, for example in terms of regional or world mandate. More detailed survey data would be necessary to this end. Nevertheless, we are confident that, despite these drawbacks, the study advances our knowledge on the role of EM in DM knowledge creation.

Figure 1 – Direct and indirect effects of host and home LAs

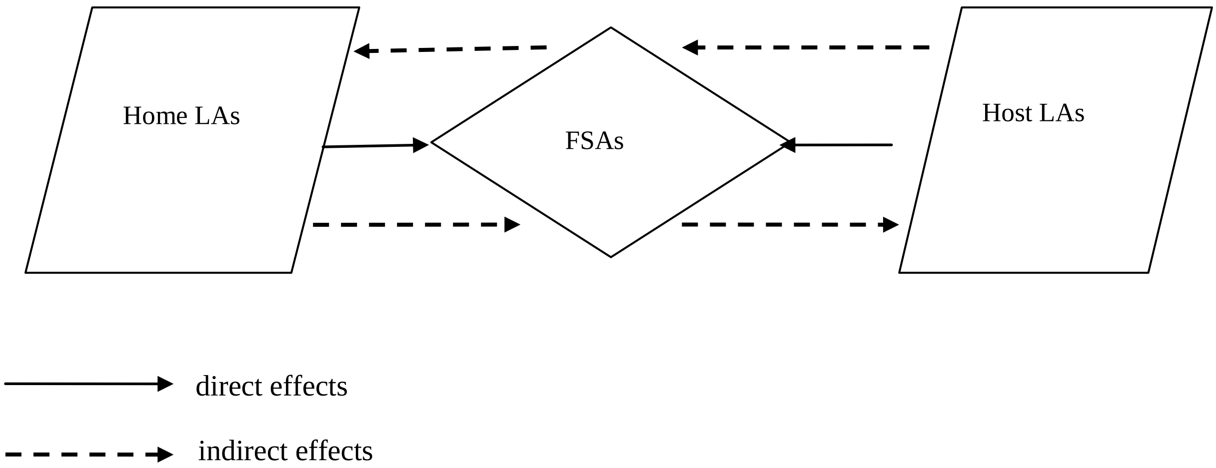

Figure 2 –Number of R&D offshoring investments hosted by BRICST in medium technology-intensive sectors in *R*, *D* and *A* type of research activities

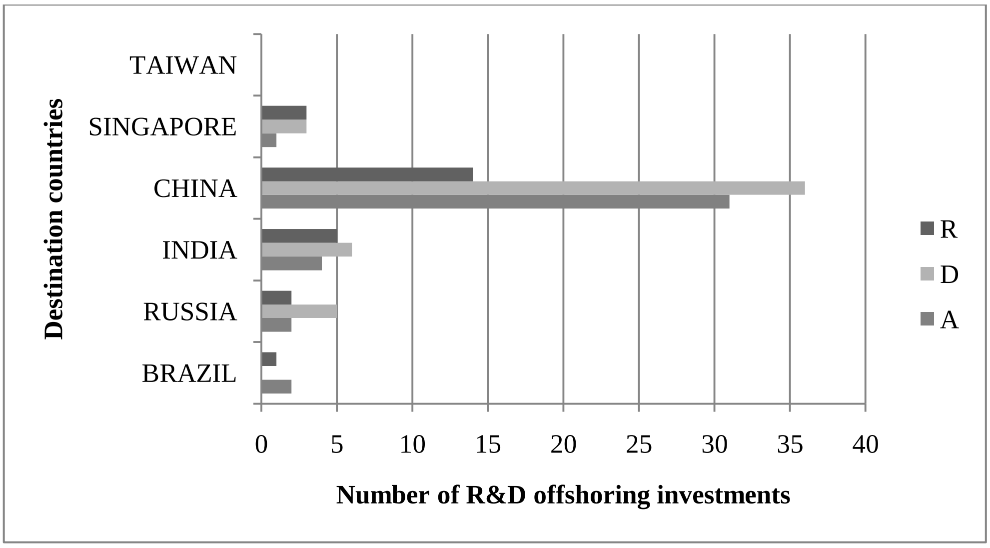

Figure 3 –Number of R&D offshoring investments hosted by BRICST in high technology-intensive sectors in *R*, *D* and *A* type of research activities

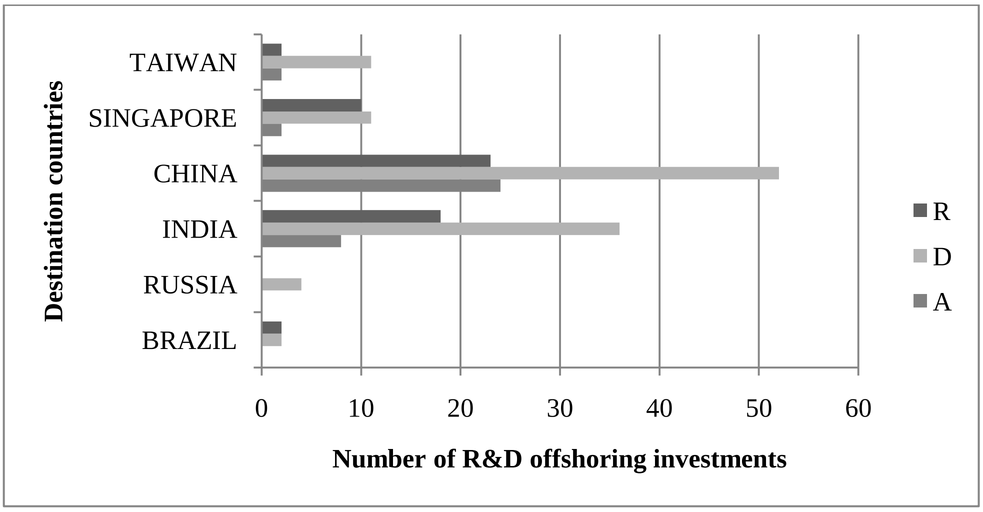

Figure 4 –Number of R&D offshoring investments hosted by BRICST in the knowledge-intensive sectors in *R*, *D* and *A* type of research activities

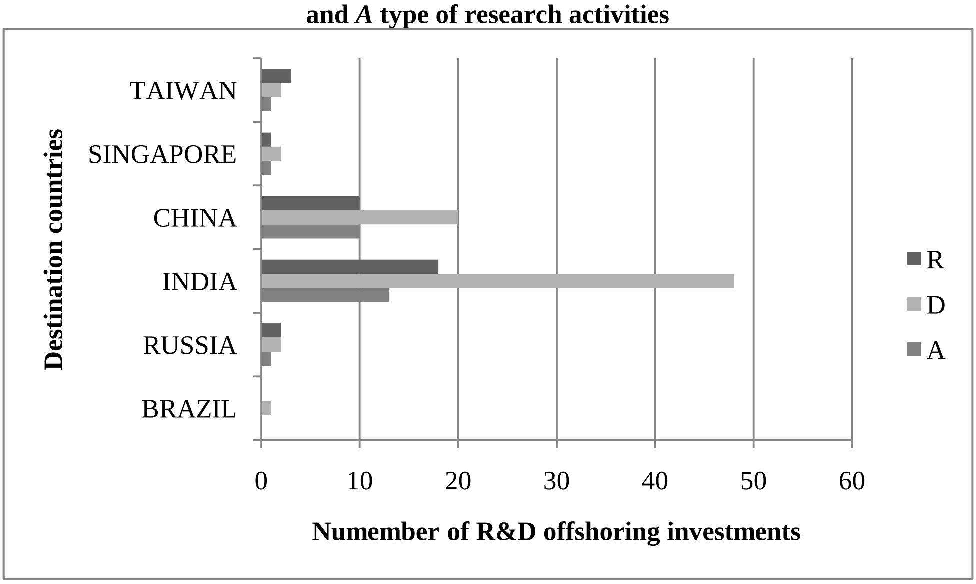

Table 1 – Descriptive statistics and correlation matrix

		Mean	Std. Dev.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	INTERFIRM	266	722	1									
(2)	FINANCIAL SECTOR	3.01	1.64	0.332***	1								
(3)	OPENNESS	7.18	7.16	0.068	-0.05	1							
(4)	EDUCATION	24.06	8.73	0.186***	0.233***	0.043	1						
(5)	POPULATION	3,564,117	4,320,656	0.061	0.304***	-0.16**	0.048	1					
(6)	PATENT PROPENSITY_EE	-0.24	0.27	0.121*	0.174***	-0.06	0.207***	0.296***	1				
(7)	PATENT PROPENSITY_I	-0.10	0.23	0.034	0.248***	-0.15**	0.119*	0.140**	0.058	1			
(8)	PATENT PROPENSITY_C	-0.03	0.21	0.115*	0.225***	-0.08	0.111*	0.096	-0.31***	0.045	1		
(9)	PATENT PROPENSITY_ME	0.08	0.23	-0.18***	-0.34***	0.155**	-0.19***	-0.30***	-0.52***	-0.26***	-0.32***	1	
(10)	PATENT PROPENSITY_O	0.10	0.31	-0.07	-0.13**	-0.19***	-0.21***	-0.13**	-0.35***	-0.21***	-0.03	0.198***	1

Table 2 - Sperman's correlation between categories and number of region in each category

	Correlation	Number of regions
	HOME	*57*
HOST_R_m	0.1925***	*9*
HOST_D_m	0.3548***	*20*
HOST_A_m	0.2521***	*15*
HOST_R_h	0.4295***	*18*
HOST_D_h	0.5528***	*28*
HOST_A_h	0.412***	*17*
HOST_R_ks	0.3407***	*10*
HOST_D_ks	0.4464***	*19*
HOST_A_ks	0.3801***	*13*

***p≤0.001

Table 3 - Econometric results

	Model 1						*Model 2*						*Model 3*					
	mR		***mD***		***mA***		***hR***		***hD***		***hA***		***ksR***		***ksD***		***ksA***	
Dep. Variable: *logHOMEKC*	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.	Coef.	St.Err.
HOMEHOST_*zk*	0.261	0.699	-0.281	0.444	-0.444	0.555	0.167	0.393	0.115	0.416	0.262	0.440	-0.024	0.571	0.057	0.414	0.635	0.414
ONLYHOST_*zk*	1.217	0.936	0.604	0.664	-1.223 *	0.674	-0.201	0.721	-0.631	0.854	-0.666	0.744	-0.112	0.880	-0.244	0.659	1.792 **	0.868
ONLYHOME	0.493 **	0.208	0.492 **	0.206	0.486 **	0.207	0.597 ***	0.206	0.571 ***	0.205	0.572 ***	0.205	0.461 **	0.200	0.487 **	0.199	0.473 **	0.196
<u>Controls</u>																		
INTERFIRM	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000	0.000
PUBLIC SECTOR	0.083	0.264	0.146	0.260	0.118	0.261	-0.048	0.283	-0.092	0.287	0.063	0.276	0.209	0.274	0.206	0.274	0.228	0.270
FINANCIAL SECTOR	0.183 ***	0.050	0.179 ***	0.050	0.169 ***	0.049	0.122 **	0.048	0.135 ***	0.047	0.116 **	0.047	0.164 ***	0.046	0.157 ***	0.046	0.155 ***	0.045
OPENNESS	-0.053 ***	0.008	-0.053 ***	0.008	-0.053 ***	0.008	-0.052 ***	0.008	-0.051 ***	0.008	-0.053 ***	0.008	-0.052 ***	0.008	-0.052 ***	0.008	-0.051 ***	0.008
EDUCATION	0.021 ***	0.007	0.022 ***	0.007	0.021 ***	0.007	0.020 ***	0.007	0.023 ***	0.007	0.020 ***	0.007	0.022 ***	0.007	0.022 ***	0.007	0.021 ***	0.007
POPULATION	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000
ATTRACTIVENESS	-0.484 ***	0.174	-0.537 ***	0.175	-0.482 ***	0.175	-0.473 ***	0.170	-0.457 ***	0.169	-0.476 ***	0.169	-0.480 ***	0.168	-0.467 ***	0.167	-0.462 ***	0.165
PATENT PROPENSITY *EE*	1.127 ***	0.342	0.969 ***	0.341	1.098 ***	0.340	1.051 ***	0.334	1.064 ***	0.329	1.086 ***	0.330	0.949 ***	0.329	0.926 ***	0.328	0.843 ***	0.326
PATENT PROPENSITY *I*	0.662 **	0.272	0.615 **	0.269	0.631 **	0.271	0.582 **	0.265	0.543 **	0.262	0.577 **	0.262	0.603 **	0.258	0.583 **	0.259	0.558 **	0.255
PATENT PROPENSITY *C*	0.529	0.382	0.488	0.378	0.539	0.380	0.619 *	0.373	0.583	0.369	0.579	0.370	0.356	0.370	0.368	0.367	0.336	0.363
PATENT PROPENSITY *ME*	-0.343	0.418	-0.596	0.418	-0.354	0.411	-0.374	0.405	-0.371	0.396	-0.300	0.397	-0.345	0.397	-0.435	0.399	-0.452	0.392
VALUE _*zk*	-0.000	0.011	0.006 **	0.002	0.001	0.004	-0.004	0.003	-0.003 **	0.001	-0.013 *	0.007	0.009	0.010	0.011	0.011	-0.018 **	0.008
BRAZIL_*z*	-1.030	1.072	-0.366	0.827	0.879	0.835	-0.128	0.659	-0.339	0.672	-0.375	0.661	-6.256	6.480	-7.435	6.468	-0.543	1.201
CINA_*z*	-0.110	0.290	-0.349	0.383	0.329	0.427	0.728 **	0.300	0.884 ***	0.265	0.873 ***	0.275	0.010	0.376	-0.123	0.416	0.283	0.351
INDIA_*z*	0.244	0.362	0.395	0.375	0.242	0.355	0.665 **	0.284	0.751 **	0.324	0.584 *	0.302	0.511 *	0.295	0.583 **	0.293	0.312	0.287
RUSSIA_*z*	0.427	0.522	0.154	0.424	0.469	0.454	-0.257	0.625	0.414	0.759	-0.049	0.651	-2.170 *	1.283	-2.466 **	1.226	-1.309	1.311
SINGAPORE_*z*	0.386	0.838	0.728	0.546	0.300	0.600	-0.726 *	0.386	-0.727 *	0.380	-0.678 *	0.364	-1.042 *	0.624	-1.128 *	0.616	-0.743	0.582
TAIWAN_*z*							-0.181	0.370	-0.026	0.373	-0.113	0.393	-0.484	0.858	-1.840	1.414	-0.355	0.849
NORTHAMERICA	-0.793 ***	0.294	-0.833 ***	0.290	-0.760 ***	0.294	-0.726 **	0.286	-0.738 ***	0.281	-0.737 ***	0.284	-0.809 ***	0.279	-0.771 ***	0.280	-0.730 ***	0.275
WESTEUROPE	0.154	0.216	0.127	0.215	0.146	0.216	0.153	0.212	0.146	0.209	0.134	0.210	0.138	0.208	0.150	0.208	0.163	0.205
_cons	3.327 ***	0.318	3.281 ***	0.315	3.333 ***	0.317	3.386 ***	0.308	3.271 ***	0.306	3.382 ***	0.305	3.143 ***	0.304	3.172 ***	0.303	3.108 ***	0.299
rho _cons	0.039 ***	0.006	0.043 ***	0.006	0.040 ***	0.006	0.040 ***	0.006	0.040 ***	0.006	0.042 ***	0.006	0.041 ***	0.006	0.040 ***	0.006	0.040 ***	0.006
sigma _cons	0.836 ***	0.039	0.827 ***	0.039	0.834 ***	0.039	0.814 ***	0.038	0.804 ***	0.038	0.807 ***	0.038	0.801 ***	0.038	0.800 ***	0.038	0.789 ***	0.037
TEST OF COMPLEMENTARITY																		
chi2	1.66		4.31**		0.19		0.1		0.04		0.23		0.16		0.07		3.31*	

*** p<.01; ** p<.05; * p<.10.

Table A.1- fDi Market, OECD and EUROSTAT sectoral breakdowns, and the sectoral aggregations adopted.

fDi Market aggregations, SIC codes in parethesis	OECD /EUROSTAT, NACE Rev. 1.1 codes in parenthesis	Aggregations adopted
	Low-technology	
Beverages (208) Food & Tobacco (01, 02, 07, 08, 09, 201, 202, 203, 204, 205, 206, 207, 209, 21, 54) Paper, Printing & Packaging (26, 27) Textiles (22, 23, 31, 561, 562, 564, 565, 566) Wood Products (24, 25)	Paper printing (21+22) Textile and clothing (17 through 19) Food, beverages, and tobacco (15+16) Wood and furniture (20+36.1)	***Medium (m)***
	Medium-low-technology	
Alternative/Renewable energy (2819, 2869) Building & Construction Materials (17, 324, 327, 5032, 5033, 5039, 5211) Coal, Oil & Gas (12, 13, 29, 554) Consumer Products (387, 391, 393, 394, 395, 396, 399, 523, 525, 526, 527, 53?, 563, 569, 57, 59, 76) Metals (10, 33, 34) Rubber (30)	Rubber and plastic products (25) Shipbuilding (35.1) Other manufacturing (36.2 through 36.6) Non-ferrous metals (27.4+27.53/54) Non-metallic mineral products (26) Fabricated metal products (28) Petroleum refining (23) Ferrous metals (27.1 through 27.3+51/52)	
	Medium-high-technology	
Automotive Components (3714) Automotive OEM (3711, 3713, 551, 552, 553, 75) Chemicals (281, 2833, 284, 285, 286, 287, 289, 8731) Engines & Turbines (351?) Industrial Machinery, Equipment & Tools (352, 353, 354, 355, 356, 358, 359, 361?, 382) Non-Automotive Transport OEM (373, 374, 375, 379, 3715, 3716, 555, 556, 557, 558, 559) Plastics (282)	Motor vehicles (34) Electrical machinery (31) Chemicals (24-24.4) Other transport equipment (35.2+35.4+35.5) Non-electrical machinery (29)	
	High-technology	
Aerospace (372) Biotechnology (2836, 8731) Business Machines & Equipment (357) Communications (366, 482, 483, 484, 489) Consumer Electronics (363, 365, 386) Electronic Components (362, 364, 3671, 3672, 3677, 3678, 3679, 369) Medical Devices (384, 385) Pharmaceuticals (2834, 2835, 8731, 8734) Semiconductors (3674, 3675, 3676)	Aerospace (35.3) Computers, office machinery (30) Electronics-communications (32) Pharmaceuticals (24.4) Scientific instruments (33)	***High (h)***
Business Services (731, 732, 733, 734, 735, 736, 738, 81, 82, 871, 872, 8732, 8733, 874) Financial Services (60, 61, 62, 63, 64, 67) Software & IT services (737)	Water and Air Transport (61, 62), Post and telecommunications (64), Financial internediation, insurance, pension funding and other auxiliary activities (65, 66, 67), Real estate activities (70), Renting of machinery and equipment etc (71), Computer and related activities (72), Research and development (73), Other business activities (74), Education, Health and social work, recreational, cultural and sporting activities (80, 85, 92)	***Knowledge-Intensive Services (ks)***

Source: Authors' elaboration on Hatzichronoglou, 1997, EUROSTAT, 2009, and fDi Market database.

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[i] Of the 30 OECD members, the 21 countries of our sample are: Australia, Austria, Belgium, Canada, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, South Korea, Luxemburg, the Netherlands, Norway, Slovak Republic, Spain, Sweden, the United Kingdom, and the United States. Due to lack of some of the regional data we excluded additional 9 regions (2 Canadian regions, 2 Spanish autonomous regions and the Canary Islands, 2 Italian autonomous provinces, and Alaska and Hawaii in the US).

[ii] The Nomenclature of Territorial Units for Statistics (NUTS, from the French 'nomenclature d'unités territoriales statistiques') has been developed by the European Union to have a uniform geographical breakdown for statistics purpose and for policy-making. REGPAT relies on the NUTS version available on July 2007. However, minor differences exist between TL and NUTS regions for some EU countries. See Maraut et al. (2008) for further details.

[iii] A possible solution to the collinearity problem would be to drop the constant in the models estimated. However, the *spatreg* STATA command used here does not allow this option. Consequently, our complementarity test is performed on three ($HOMEHOST_{zk}$, $ONLYHOST_{zk}$ and *ONLYHOME*) out of our four categories, according to the following rule:

$$\theta_{11} - \theta_{10} \geq \theta_{01} \quad (4^*),$$

Nonetheless, when NOHOMEOFF is used as the benchmark against the three other dummies, $\theta_{00} = 0$. Accordingly, the inequality tests involving four (Equation 4) or three dummies (Equation 4*), respectively, are equivalent.