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DRUID Working Paper No. 10-19

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This version: 23rd July 2010
Word count, main body: 8,592

Abstract:
This paper investigates the relationship between home and offshore R&D activities on the knowledge production of the investing home region. Debate is ongoing on whether R&D offshoring complements the R&D performed at home. In the light of increased offshoring of innovative activities to emerging countries, we explicitly focus on Brazil, Russia, India, China, Singapore and Taiwan. We suggest that complementarity should obtain, when home region and offshore R&D activities are dissimilar as well as when offshore R&D activities is about modular and less complex technologies. We ground our predictions on arguments related to geographical technological specialisation and reverse knowledge transfer from offshore locations to home regions within the more general open innovation trend. Using a theoretical framework based on the international business literature and the regional system of innovation perspective, we estimate a knowledge production function

for a sample of 221 regions from 21 OECD countries with home region patent applications as the dependent variable. Our test supports our predictions on the complementarity between home region and offshore R&D.

Keywords: Home Region R&D; Offshore R&D; Knowledge Production; Complementarity; Emerging Countries

Jel codes:

ISBN 978- 87-7873-301-6

1. Introduction

Organisations have over the past couple of decades increasingly turned towards offshoring as an important means of achieving competitive advantage. The level of offshore activities has therefore grown tremendously and the growth rate of activities offshored to lower-wage foreign countries has in particular been outspoken (Trefler, 2005). While offshoring of tangible commodities has a relatively long history, offshoring of research and development (R&D) activities to lower-income countries is of more recent date (Lewin, Massini and Peeters, 2009). Indeed, within the trend of an increasing internationalization of economic activities, available statistics show a recent change in the location of overseas innovative activities (UNCTAD, 2005) with significant proportions of R&D being moved to countries of developing Asia (Beausang, 2004) — countries that have emerged as new technology producers (Athreye and Cantwell, 2007).

This development could be regarded as highly problematic from the point of view of developed regions (see for instance, Manning, Massini and Lewin, 2008). Recent economic geography literature has indeed recognized R&D and innovation to be at the core when it comes to explaining differences in regional development and growth (e.g., Crescenzi, Rodriguez-Pose and Storper, 2007; Frenken, Van Oort and Verburg, 2007; Lehto, 2007). Specifically, this stream of research suggests that regional geographically bound R&D positively impacts on economic development at the regional level, as knowledge spillovers appear to have strong distance decay effects (see also, Bode, 2004; Ó hUallacháin and Leslie, 2007; Rodríguez-Pose and Crescenzi, 2008; Paci and Usai, 2009). Somewhat in contrast to this view, research on the internationalization of R&D activities has shown that multinational enterprises (MNEs) are increasingly internationalizing their R&D activities to tap into the technological capabilities of specific host locations to ultimately develop the firms' own ability to combine knowledge into innovations (e.g., Cantwell, 1995; Patel and Vega, 1999; Verspagen and Schoenmakers, 2004).

However, the former set of contributions on regional development and R&D does not address the international division of labour in knowledge production and the latter set of contributions all consider the cases where MNEs engage in home-base augmenting investments in other developed regions. Hence, little is known about how the offshoring of R&D activities to fast-growing emerging economies may affect knowledge generation in the home region. This paper contributes to these streams of literature by being the first to investigate whether and how R&D offshoring to fast-growing emerging economies affects the knowledge creation of the OECD regions from which the investment initially departed. To this end, we focus on R&D offshore in fast-growing emerging economies, including Brazil, Russia, India, China, Singapore and Taiwan (hereafter BRICST) as empirical evidence suggests that this group of countries receive the lion share of R&D investments from advanced regions (UNCTAD, 2005; Belderbos and Sleuwaegen, 2007). In addition, we focus on the type of R&D offshoring which Kotabe and Murray (2003: 9) call "offshore subsidiary sourcing"—others have referred to the phenomena as "captive outsourcing" (e.g., Kedia and Mukherjee, 2008; Lewin, Massini and Peeters, 2009). That is, R&D activities which are offshored from MNEs with headquarters located in the OECD regions to subsidiaries located in the BRICST countries. Therefore, the term "offshoring" is here used interchangeably with internationalization. Specifically, we ask whether R&D offshoring complements R&D conducted at home in affecting the knowledge production of the investing region in terms of home region patent applications.

While it is a possibility that offshoring will stifle innovative activity in the home region (see e.g., Teece, 1987; Manning, Massini and Lewin, 2008) it is also possible that R&D offshoring to emerging economies will complement and hence enhance the value of R&D carried out in the home region (Kotabe, 1990; Verspagen and Schoenmakers, 2004). Mudambi (2008) suggests indeed that firms from advanced regions are finding that value-added is becoming increasingly concentrated in the upstream (R&D) and downstream (marketing) ends of the value chain. For this reason, firms focus on these activities at home, while offshoring the middle of the value chain (manufacturing and standardized services). Following Lewin et al. (2009), we push this argument further: Not only it does make sense to offshore the middle of the value chain, but part of the R&D activity can be offshored as well. We argue that this may happen without necessarily damaging the efficiency of the home region R&D base.[1]

We assume that 1) firms in advanced regions tend to have a comparative advantage in R&D within the most advanced technologies, 2) less complex technologies are easier to codify and transfer across borders, and 3) modular technologies require coordination at the organisational and knowledge level, which in multi-unit firms may be better orchestrated from the home R&D laboratory, and these technologies are also easier to transfer across borders. Based on these assumptions, we propose that offshore R&D which a) is not high-technology intensive and, therefore, less complex; and b) concerns modular technologies,

[1] Note that an observed complementarity effect between offshore and home region R&D in the home production of knowledge implies that investment in offshore R&D makes home region R&D more effective in producing innovations as reflected in home region patents (and vice-versa). A complementarity effect says nothing, however, about whether or not offshore R&D is associated with higher (or lower) investments in home region R&D *per se*. Nevertheless, if a complementary effect is obtained, it can be argued that there is a stronger incentive to invest in home region R&D for a given region where firms have offshored R&D as compared to other regions where firms have made no such an investment. For formal representation of how to measure complementarity, see Section 7 below.

should be complementary to the R&D carried out in the more advanced home regions. In other words, we posit that R&D offshored to BRICST countries is complementary, when it is dissimilar to the R&D carried out in the home region and less complex (e.g., medium technology-intensive R&D activities) and when it requires systemic integration and is easier to transfer across borders (e.g., R&D in software and knowledge-intensive services). In contrast — and based on the same logic — we conjecture no complementarity effect between offshore R&D in high-technology sectors and home region R&D in affecting knowledge production in the home region.

We resort to a sample of 221 large OECD regions for which we collected data on their patenting activity, socio-economic indicators, and information on R&D offshoring investments towards BRICST countries. Our regional focus is suggested theoretically by the regional system of innovation (RSI) literature (e.g, Cooke, Uranga and Etxebarria, 1997; Asheim and Gertler, 2005) and the distributed or open innovation approach (von Hippel, 1988; Chesbrough, 2003). This *meso* level of analysis has the advantage to overcome the limitations of a country-level investigation, which is a far too aggregate unit of analysis, and allows us to capture the systemic and "open" aspect of knowledge production (Braczyk, Cooke and Heidenreich, 1998).

The paper is organised as follows. Section 2 discusses the theoretical debate on the effects of home and offshore R&D on home innovation activity. Section 3 illustrates firm's location advantage of R&D offshoring, while Section 4 discusses the arguments supporting our forecasts. The data and sample are described in Section 5, while Section 6 describes the variables and Section 7 the methodology. The results of the econometric analysis are presented in section 8. A few conclusions are drawn in section 9.

2. The theoretical debate

Spatially-bounded factors are explicitly taken into consideration by the RSI approach (Braczyk, Cooke and Heidenreich, 1998), which has been developed based on the literature on national system of innovation (Freeman, 1987; Lundvall, 1992; Nelson, 1993). In particular, the RSI approach is based on the idea that regional borders (rather than national) better define the ways innovation is created by strongly interrelated local actors (Asheim, 1996; Braczyk, Cooke and Heidenreich, 1998; Cooke, 2005). Firms interact with other firms, research institutes, financial and public institutions, and their interactions are encouraged by face-to-face and continuous contacts (Keeble et al., 1999; Gertler, 2003). Local actors share common values, norms and standards that have a marked regional dimension. Differences among regions within the same country can be recognized in terms of regional governance of innovation, regional specialisation and evolution, and core/periphery differences in innovation development (Howells, 1999). The empirical significance of geographical proximity has been also confirmed in studies of knowledge spillovers (Jaffe, Trajtenberg and Henderson, 1993; Feldman, 1994; Audretsch and Feldman, 1996) as well as by the literature on clusters (Porter, 1990; Beaudry and Breschi, 2003; Iammarino and McCann, 2006). Specifically, these streams of research point out that problems related to the codification of knowledge may arise in a large number of cases, and hence, hamper knowledge transmission across larger geographical distances (Anselin, Varga and Acs, 1997; Bode, 2004; Crescenzi, Rodriguez-Pose and Storper, 2007; Frenken, Van Oort and Verburg, 2007; Lehto, 2007; Rodríguez-

Pose and Crescenzi, 2008; Paci and Usai, 2009). Similarly, some researchers have seen the globalization of R&D and innovation as a factor that could possibly erode the R&D-based stronghold of advanced regions as they forecast an incremental shift of R&D activities towards emerging economies where science and engineering talent continues to grow (Manning, Massini and Lewin, 2008). However, other researchers such as Cantwell (1995), Patel and Vega (1999) and Le Bas and Sierra (2002) have shown that although large firms typically have the largest share of their R&D in the home country, a substantial part is executed in foreign locations with the ultimate aim of sourcing new complementary knowledge.

This evidence may seem to challenge the RSI approach. However, in this context, Verspagen and Schoenmakers (2004: 24) argue that this tendency to perform R&D abroad implies a strengthening of the notion of RSI, rather than the opposite. The line of argument rests on the idea that due to the existence of specific skills and competencies in people who are not perfectly mobile, technological capabilities of specific regional innovation systems cannot be easily tapped into from a distance (Morgan, 2004). Thus, an MNE aspiring to make use of such specific knowledge will have to establish or acquire physical presence in the region. Similar arguments has been made by Cantwell and Iammarino (2001). Nonetheless, and, as pointed out above, these contributions all consider the cases where MNEs engage in home-base augmenting activities in other developed regions. Here, we put under scrutiny how offshoring of R&D activities to fast-growing emerging economies may affect the efficiency of knowledge production in the home region.

3. Location advantages of R&D offshoring

Offshoring is a part of the global disaggregation of the value chain, and, as pointed out by Mudambi (2008), provides a critical interface for the interconnected issues of geography and the MNE. This disaggregation is the outcome of firms combining the comparative advantages of different geographic locations with their own resources and competencies to create and sustain competitive advantage (Dunning, 1977; Kogut, 1985; McCann and Mudambi, 2005). In turn, the interplay between comparative advantage and competitive advantage determines the optimal location of value chain components (i.e., offshoring decisions). Differences in factor costs have strong implications for where a firm should locate parts of its value-added chain internationally (Kogut, 1985). In this context, a firm should locate its activities in those regions and countries that possess a comparative advantage in terms of the relevant intensive factor. Accordingly, because regions and countries differ in their relative abundance and quality of production factors — which will be reflected in factor costs — and because the intensity of factors use varies along the value-added chain, the distribution of the type of value added activities between regions and countries will tend to differ. A key driver of this process has had to do with the implied increased division of labour, where the offshoring firm can focus on certain higher value activities in the home region at the expense of other lower value activities which the firm can handle in emerging developing countries, typically at lower costs (Stopford and Wells, 1972; Ramamurti, 2004; Doh, 2005; Mudambi, 2008).

As far as R&D offshoring is concerned, empirical evidence suggests that this type of offshoring is becoming a possibility due to advances in information and communication technology (ICT) that makes information exchange and interaction over larger distances much more workable also in the context of R&D and innovation

(Howells, 1995; Manning, Massini and Lewin, 2008).[2] It should be noted, however, that the transfer of knowledge over large geographical distances is a non-trivial matter, even with the existence of modern ICTs (Bulte and Moenaert, 1998; Morgan, 2004), but it is beyond the scope of this paper to enter this discussion.

In this paper we posit that location-specific advantages can emerge from locating R&D in emerging countries. A very important part of the advantage from R&D offshoring is obtained because these locations can offer specific high-quality R&D services at a low costs. Another part has to do with the fact that the regional science and technological base vary “from country to country and from region to region” and “is said to constitute the location-specific supply base of technological and knowledge externalities that firms draw upon for their competitiveness.” (Amin and Cohendet, 2005: 467). Indeed, also emerging countries may offer such supply — India’s supply of engineers and strength in software development is a prime example of this, while Taiwan’s strength in computer hardware is another. In the words of Lewin et al. (2009: 920): “…Asian countries such as India and China, and certain countries in Eastern Europe and Latin America, are becoming recognised as suppliers of highly qualified engineering and science talent.” Strongly related, there is evidence of increasing clustering of R&D activities in emerging economies (see e.g., Chen, 2004; Arora and Gambardella, 2005; Tan, 2006). This development of knowledge clusters in emerging countries also allows MNEs to plug into these science and technology systems through subsidiary location choices.

[2] However, note there are several mechanisms that allows MNEs to transfer tacit knowledge, including communities of practice and knowledge enablers. Gertler, M. S. (2003). Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there), *Journal of Economic Geography*, 3(1): 75-99.

4. The complementarity between home region and offshore R&D

While it is clear that emerging countries location advantages offer advantages to MNEs, the outcome is less clear when it comes to the effect on the knowledge production in the home region of the MNE. Indeed, one possibility is that R&D offshoring activities may be of a “home-base damaging” nature, that is, R&D offshoring activities may be reducing the effectiveness of knowledge production in the home country. Alternatively, there is also the possibility that R&D offshore activities may be of a “home-base augmenting” nature, thus complementing the efficiency of home region R&D investments on the knowledge production of the home country. It is also a possibility that most knowledge clusters in advanced countries and regions will be relatively unaffected because of what they have to offer will continue to be of very high value (Doh, 2005; Manning, Massini and Lewin, 2008; Lewin, Massini and Peeters, 2009). However, very little empirical evidence on the final effects is available, as far as our knowledge is concerned.

In this paper, we posit that complementarity effects will emerge due to geographical technological specialisation and reverse knowledge transfer. First, when the R&D activities of the home region are dissimilar to the offshore R&D activities, MNEs in the home region can focus on certain types of R&D and offshore other parts of the R&D. As noted by Quinn (1992: 37), “virtually all staff and value chain activities are activities that an outside entity, by concentrating specialists and technologies in the area, can perform better than all but a few companies for whom that activity is only one of many”. Especially, given that there is a shortage of supply of engineers and scientists in most advanced countries, there may be a strong need to focus on some R&D activities in the home region and not others. Similarly, R&D offshoring may favour an increased focus on an organisation’s core competencies in the home region. Offshoring some activities from the home region may allow the firm to increase managerial attention and resource allocation to those tasks that it does best in that location and to rely on management teams in other locations to oversee tasks at which the offshoring firm is at a relative disadvantage at the home location.

Second, knowledge developed in offshore locations by foreign affiliates may be “reverse” transferred to the parent (Mansfield and Romeo, 1984). In this context, the international business and management literature has documented that MNEs increasingly rely on this less conventional knowledge transfer type, going from subsidiaries to the parent company in order to source new complementary knowledge from distant locations (Ghoshal, Korine and Szulanski, 1994; Mudambi and Navarra, 2004). Subsequently, parent embeddedness in the home RSI makes possible the exchange of knowledge and mutual learning through trust-based local relationships (Andersson, Forsgren and Holm, 2002; Forsgren, Holm and Johanson, 2005). Thus, offshore knowledge is fed into the knowledge production in the home region, thereby enhancing the productivity of home region knowledge production. Reverse knowledge transfer, which is based upon the relationship between firm-internal R&D and external knowledge sourcing, is further strengthened by the recent open innovation trend (Chesbrough, 2003). To be sure, we are currently witnessing a change in firms’ knowledge strategies in the form of a movement from more “closed” to more “open innovation”, whereby firms increasingly draw knowledge from a range of external actors to develop and commercialize new technology (Chesbrough, 2003). In this light, the use of knowledge developed in offshore locations may be seen as part of this broader open innovation trend, where firms make location choices to open up to external sources of knowledge across multiple geographical locations. Specifically, firms in given regions need to specialize their knowledge production and at the same time be open to different external sources of knowledge that may be present in different locations around the globe — including in emerging economies — to remain effective in terms of innovation production.

However, to assess the complementarity between home and offshored R&D we need to consider the nature and technological intensity of R&D offshoring. In particular, we have assumed that firms in advanced regions tend to have a comparative advantage in R&D within the most advanced technologies. For this reason, we expect that there will be no complementarity effect between offshore R&D in high-technology sectors and home region R&D in affecting innovation production in the investing home region. Despite the fact that the development of R&D in these sectors may benefit in principle from relative cost advantages, extant research documents that these emerging economies still need to complete their technological upgrading (Athreye and Cantwell, 2007) and, as a result, their real contribution to the knowledge production of advanced locations may be limited.

In addition, we expect offshore R&D in medium technology-intensive and software and knowledge-intensive services sectors to be complementary to home region R&D activities. The reason for our expectation is twofold. First, innovation literature has shown that less complex technologies (e.g., medium technologies) are easier to transfer from the offshore locations to the home regions because they could be easier to codify than the most advanced technologies (Cantwell and Santangelo, 1999). Second, research in the innovation field has shown that modular technologies (e.g., software and knowledge-intensive services) may be easier to transfer (Kotabe, Parente and Murray, 2007) and to integrate (Brusoni and Prencipe, 2001) with other technologies. These relatively lower costs of transferring and integrating technologies developed offshore in the production of knowledge in home region, in turn, increases the probability of obtaining a complementarity effect between offshore and home region R&D activities in the production of knowledge in the home region.

5. Data and sample

The sample of analysis refers to 221 regions of 21 OECD countries from which R&D investment projects departed to BRICST. For these regions, we built a dataset relying on three main sources: the OECD REGPAT database (version January 2010), the fDi Market database, and the OECD Regional Database (RDB).

The OECD REGPAT collects patent applications filled at the Patent Cooperation Treaty (PCT) at the international phase that have been designated at the European Patent Office (EPO). The PCT procedure is an alternative route to the direct applications at national/regional patent offices. This procedure allows seeking for patent rights in multiple countries with a single application in a single language, although only the designated national (e.g., the USPTO) or regional (e.g., the EPO) patent office has the authority to grant a patent. The PCT procedure is considered an international procedure to seek patent protection because it does not suffer from bias towards any particular country (Le Bas and Sierra, 2002; Khan and Dernis, 2006). In the OECD REGPAT database, the PCT applications have undergone a procedure of "regionalization", which linked the address of both inventor and applicant to regional codes. The "regionalization" process has involved 42 countries (Maraut et al., 2008), of which 30 are OECD members.[3] The sub-national units used are the Territorial

[3] The OECD members are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Luxemburg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Due to lack of some of the regional data we excluded Japan, Turkey, Mexico, Iceland, Denmark, Switzerland, New Zealand, Poland and Portugal, and 9 regions (2 Canadian regions, 2 Spanish autonomous regions and the Canary Islands, 2 Italian autonomous provinces, and Alaska and Hawaii in the US).

Grids by OECD (2008). According to this system, the regions within the OECD member countries have been classified into two hierarchical levels: Territorial Level 2 (TL2) and Territorial Level 3 (TL3). The TL2 is more aggregated and it consists of 335 regions and it is the division adopted in this study. The TL3 is the lowest, with 1679 regions. For most of the European Union countries, the Territorial Levels corresponds to the Eurostat classification (NUTS).[4] REGPAT allows us to extract information about the technological content of the patents. In particular, drawing on the International Patent Classification (IPC, 8th version) codes, we are able to group the technological field of each patent into of one of the following technological groups (Schmoch, 2008): 1) Electrical Engineering, 2) Instruments, 3) Chemistry, 4) Mechanical Engineering, and 5) Other fields.

The second source from which our data were drawn is the fDi Market database. By relying on media sources and company data, fDi Market collects detailed information on cross-border greenfield and expansion investments worldwide since 2003. fDi Market data are based on the announcement of the investment and this has the advantage of daily-updated data. For each FDI project, fDi Markets reports information on the *investment* (e.g., the leading industry sector of the investment), the home and host country, region and city involved, and on the investing company (e.g., location, parent company). For the sake of this research, we converted the sectors provided by fDi Market database for the offshoring investments into the OECD classification based on the R&D intensity of the sector (1997) (i.e., High-

[4] 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. NUTS comprises three levels. NUTS divisions do not always correspond to administrative divisions within the country. REGPAT relies on the NUTS version available in July 2007. However, differences exist between TL and NUTS regions for some EU countries. Being small countries, for Belgium, Greece and the Netherlands, the NUTS 2 level corresponds to TL3. For United Kingdom, the NUTS 1 corresponds to TL2. For Denmark, which has not a NUTS 2 divisions, the TL2 corresponds to the TL3/NUTS3 regions.

technology, Medium-high technology, Medium-low technology, and Low-technology sectors). Due to the very small number of offshoring investments in Medium-low and Low-technology industries, for the sake of this study we aggregated these categories into the one which we labelled as Medium. In addition, as offshoring investments also occurred in knowledge-intensive services, we relied on the EUROSTAT (2006) classification. In particular, both OECD and EUROSTAT classifications are based on NACE Rev. 1.1. Table 1, column 1 lists the fDi Market sectors with SIC sectors in parentheses, column 2 contains the relative OECD and EUROSTAT sectors with NACE Rev. 1.1 codes in parentheses and column 3 reports the 3 sectoral aggregations adopted in our analysis (i.e., high (H), medium (M), and knowledge-intensive services (KS)).

[Table 1, just about here]

A drawback of using fDi Market database is the fact that it collects intents of investments in the future. Therefore, some of these projects might never be realized or they might be realized in a different form than the one announced. However, we have reasons to believe that the percentage of these projects is negligible as the database is used as the exclusive source of FDI project data for the UNCTAD World Investment Report and the Economist Intelligence Unit.

Finally, in our analysis we also rely on the OECD RDB which collects socio-economic indicators of the OECD regions (e.g., demographic statistics, regional accounts, regional labour market, innovation indicators, and social indicators).

6. Variables

Dependent variable and key independent variables

To measure the knowledge production of the region from which R&D investments departed to BRICST, we took the fractional count of PCT applications aggregated by the region *i* of residence of the inventor in the year 2006-2007 (2-year average) and transformed it in logarithm (*logPAT0607*). Note that, when more than one inventor participates to the patent, the patent is equally shared among them. Therefore, for each region we counted the shares of the inventors who are resident in that region. No regions have zero patents. The fractional counts render the dependent variable more similar to a continuous variable than to a discrete variable. Moreover, the transformation in logarithm of the dependent variable is normally distributed, thus overtaking censoring problems that usually arises when dealing with patents.

Home region R&D was measured by the total R&D expenditures (US PPP) in region *i* (*RDhome*) and R&D offshoring in BRICST was measured by the number of R&D offshoring investments made by firms whose headquarter is located in region *i* (*RDoff*). Both key independent variables were calculated over the period 2003-2005, the former as a 3-year average and the latter as sum over the period.

Controls

By taking the region as unit of analysis we account for the regional systemic characteristics of knowledge production, which is not merely the result of firms that innovate in isolation, but it is affected by several elements spatially bounded (Lundvall, 1992), such as inter-firm relationships, role of the public sector, institutional set-up of the financial sector, R&D organisation. To control for such elements, we introduced a set of exogenous variables.

Following prior studies (e.g., Sterlacchini, 2008; Usai, 2008), we controlled for population density of the region (*DEN*) to proxy for inter-firm relationship under the hypothesis that in agglomerations firms' interaction and collaboration are stronger, as underlined by the studies on knowledge spillovers (Jaffe, 1986) and clusters

(Porter, 1990). The role of the public sector is accounted for by considering that some industries might benefit from the proximity to government research centres with large in-house R&D activities, which are more likely to be concentrated in the region where the country capital city is located. For this reason, we introduced a binary variable (*CAP*) taking value 1 if the region hosts the country capital (Feldman, 2003). To control for the role of the financial sector we use the share of employment in financial intermediation (*FIN_SHARE*) as a proxy for the local presence of financial institutions. The more localized are the financial institutions, the closest they are to the needs of innovative firms (Cooke, Uranga and Etxebarria, 1997). Lundvall (1992) also highlights the significance of R&D organisation in innovation systems. Unlike in the past where knowledge production mainly relied on internal R&D laboratories, lately it is increasingly the results of a more “open” process (Chesbrough, 2003) characterized by inter-firm collaborations, firm-university partnerships, start-ups, and scientists’ networks. These collaborations in innovation have also a cross-border dimension, as shown by the rise of international technological partnerships (e.g., Narula and Hagedoorn, 1999). Therefore, we controlled for international inter-regional collaboration by considering the share of patents with multiple inventors where at least one inventor is located in another country (*INTERNATCOOP*). In addition to Lundvall’s elements (1992), we considered the role of education and training as suggested by Freeman (1987) and included the share of population with tertiary level of education (*HK_SHARE*) as proxy for human capital.

Although the TL2 classification accounts for the geographical dimension and the population size of the regions in order to have a division as homogenous as possible, it is based on existent institutional divisions. Therefore, TL2 regions vary in dimension, especially in terms of population size. We account for differences in regional size by controlling for the number of inhabitants of the region (*POP*). In addition, we introduced the value of all R&D investments departing from region *i* in the given sectors H, M, and KS ($VAL_{H,M,KS}$) to control for the dimension of the region's R&D offshoring investments. Moreover, we control for the international attractiveness of the country by considering the net value of FDI inward stock - namely, FDI inward stock minus FDI outward stock – based on the UNCTAD (2008) database. This variable is built as a binary variable taking value 1 for countries with positive net values, 0 otherwise (*FDI_D*).

We also considered the different propensity to patent across technologies (Scherer, 1983; Arundel and Kabla, 1998) and we introduced in our analysis the revealed technological advantage (RTA). In particular, we control for the regional relative specialisation in each of the five groups of technologies as from the IPC codes of the patents ($adjRTA_j$ where j=1, 2, 3, 4, and 5). To this end, we calculate for each region the RTA as:

$$RTA_{ij} = \frac{P_{ij} / \sum_j P_{ij}}{\sum_i P_{ij} / \sum_{ij} P_{ij}} \quad (1)$$

where P_{ij} is the number of patents in region *i* in group of technology *j*. Thus, the index gives the share of the patents of the region *i* in group of technology *j* (numerator), weighted by the share of the patents of all regions in group of technology *j* on the all patents of the sample (denominator). As the index takes the values between 0 and +∞, we normalize it as follows so to constrain its variation between −1 and +1

$$adjRTA_{ij} = \frac{RTA_{ij} - 1}{RTA_{ij} + 1} \quad (2)$$

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

A set of controls for the destination countries of the investment has been used to account for the idiosyncrasies of the emerging economies considered, especially in terms of weak Intellectual Property Right regime that might affect FDI location choice (Lall, 2003) and MNEs' technological strategies (Zhao, 2006). Moreover, dummies for West European countries (EU15 plus Norway), and Canada and the United States are introduced (*WESTEUROPE* and *NORTHAMERICA,* respectively). All the controls variables refer to the period 2003-2005. Table A1 reports the variables included in the analysis and relative descriptive statistics.

[Table A1, just about here]

7. Methodology

Complementarity

We want to test whether R&D at home (*RDhome*) and R&D offshoring (*RDoff*) are complements in the home production of knowledge of the investing region. The complementarity concept refers to the simultaneous presence of certain elements, which reinforce the importance of each other. Complementarity arises when the marginal return to one element (which can be any practice or activity of firm, industry or region) increases as the other element increases.

An empirical test to complementarity derives from the theory of supermodularity (Milgrom and Roberts, 1990; 1995). Suppose that there are two activities, *A* and *B*. Each activity can be either performed (*A=1*) or non-performed (*A=0*). The function *F(A, B)* is called *supermodular* and *A* and *B* are said *complements* only if:

$$F(1,1) - F(0,1) \geq F(1,0) - F(0,0) \qquad (3)$$

The right-hand side of the equation defines the marginal increase of doing only activity *A* (*F(1,0)*) rather than neither of the two (*F(0,0)*). The left-hand side describes the marginal increase of doing both activities (*F(1,1)*) rather than only *B* (*F(0,1)*). Therefore, the whole equation states that the marginal increase of adding one activity (i.e. *A*), when already doing the other (the left-hand side), is higher than the marginal increase from adding one activity solely (the right-hand side). Empirically, we check the above constraint by applying the production function approach to complementarity, where *F* is the knowledge production function and R&D at home and R&D offshoring are the complements to be tested upon a set of exogenous variables θ_i (Athey and Stern, 1998; Cassiman and Veugelers, 2006; Giuri, Torrisi and Zinovyeva, 2008).

Following previous studies (Cassiman and Veugelers, 2006; Giuri, Torrisi and Zinovyeva, 2008), we generated two dummy variables, *HOME* and $OFF_{H,M,KS}$. The first accounts for the level of the region's R&D at home taking value 1 if *RDhome* is greater than regions' sample mean. The regions falling in this category are 57, which constitutes the 26% of the sample. The second dummy variable accounts for the 50 regions doing R&D offshoring (23% of the total regions), taking the value 1 if the region has done at least one R&D offshoring investment in the given sector H, M, or KS. The reason to prefer dummies over continuous variables are mainly due to the distribution of *RDoff*, which is very skewed, with many regions having zero investments and — among the investing regions — about 90% having less than 10 R&D investments. The skewness worsens when *RDoff* is taken for each of the sectors H, M, and KS.[5] Therefore, *RDoff* can be regarded as a rare event, for which

[5] Alternative methods to construct the dummy $OFF_{H,M,KS}$ have been tested. In particular, the mean and the median of both number and value of R&D investments have been used as thresholds to assign value 1 to regions standing above, 0 otherwise. However, these methods require us to drop a large number of observations, ruling out the possibility to run some of the model specifications.

already one investment is a sign of R&D offshoring activity. In addition, we believe that the control $VAL_{H,M,KS}$ described above should account for regions which have a high number of R&D offshoring investments. The same results are obtained if the total number of R&D investments is used as control. As far as *RDhome* is concerned, we rely on Cassiman and Veugelers (2006) who used a dummy to proxy for in-house R&D activity of firms. From *HOME* and $OFF_{H,M,KS}$ we constructed all possible combinations between R&D at home and R&D offshoring in the 3 sectors. In particular,

- *HOMEOFF_H* equals 1 if *HOME*=1 and at least one R&D offshoring investment in sector H has departed from the region (i.e., OFF_H=1)
- *HOMEOFF_M* equals 1 if *HOME*=1 and at least one R&D offshoring investment in sector M has departed from the region (i.e., OFF_M=1);
- *HOMEOFF_KS* equals 1 if *HOME*=1 and at least one R&D offshoring investment in sector KS has departed from the region (i.e., OFF_{KS}=1);
- *ONLYOFF_H* equals 1 if *HOME*=0 and at least one R&D offshoring investment in sector H has departed from the region (i.e., OFF_H=1);
- *ONLYOFF_M* equals 1 if *HOME*=0 and at least one R&D offshoring investment in sector M has departed from the region (i.e., OFF_M=1);
- *ONLYOFF_KS* equals 1 if *HOME*=0 and at least one R&D offshoring investment in sector KS has departed from the region (i.e., OFF_{KS}=1);
- *ONLYHOME* equals 1 if *HOME*=1 and at no R&D offshoring investment has departed from the region (i.e., $OFF_{H,M,KS}$=0);
- *NOHOMEOFF* equals 1 if *HOME*=0 and no R&D offshoring investment has departed from the region (i.e., $OFF_{H,M,KS}$=0).

Note that *ONLYHOME* and *NOHOMEOFF* are not affected by the sectoral qualification.

The model

To test the complementarity between R&D at home and R&D offshoring in H, M, and KS we estimated a knowledge production function in which *logPAT0607* is estimated as a function of combinations of R&D activities and on a set of controls. Therefore, by mean of an ML regression we estimate the following model:

$$\log PAT0607_{it} = C_{cit-1}\theta + X_{it-1}\beta + \varepsilon_i \qquad (4)$$

where i refers to the region i, t refers to 2006-2007 and t-1 to 2003-2005, and c refers to the six combinations of *HOME* and the offshoring variables accounting for the sector of the offshoring investment. C_{cit-1} measures the combination of complements of region i at time t-1. θ is the vector of the coefficients of the combinations C_{cit-1}. X_{it-1} is the vector of controls and β is the vector of coefficients of the controls.

The test of complementarity is based on the following null hypothesis:

$$\theta_{11} \quad \theta_{10} \geq \theta_{01} \quad \theta_{00} \qquad (5)$$

where the first subscript refers to *HOME* and the second subscript to each of the 3 types of offshoring investments ($OFF_{H,M,KS}$). Therefore, the rejection of the equality hypothesis means that the payoff of joint *HOME* and $OFF_{H,M,KS}$ is greater than the sum of the two events occurring separately.

Spatial dependency

Since we are conducting a regional level analysis, we also want to check whether a spatial dependence exists among them. As highlighted by previous studies (Acs, Anselin and Varga, 2002; Moreno, Paci and Usai, 2005), in cross-sectional data of geographically close units of observations it is very likely that innovation output of each unit is affected positively by the innovation performed in the neighbouring regions, which means that the error terms are correlated across observations. The spatial autocorrelation renders the OLS estimator inefficient, although it leaves the coefficients unbiased (Anselin, 1988). To deal with this problem, we firstly tested the presence of such misspecification by means of Moran's I test with a binary contiguity matrix, where the contiguity matrix takes the value of 1 if the pair of regions share a border, 0 otherwise. The binary contiguity matrix has been constructed manually to include also the islands[6] and to take into account the regions that, although not sharing a border, are separated by few kilometres of sea- or lake-water (e.g., the French region of Calais and the British region of Dover, or the US and Canadian states along the Great Lakes area). This procedure is motivated by the argument that spatial weight matrix should be chosen on the basis of a consideration on the structure of dependence, rather than on simple pre-packed description of the spatial relations (Anselin, 1988). Therefore, although we use the simplest spatial matrix to account for spatial dependence, we wanted to account for the most obvious geographical proximity among regions that do not share borders. The Moran's index of spatial correlation rejects the null hypothesis that the patents of contiguous regions are independent ($p \leq 0.01$ level of significance). Therefore, regions tend to

[6] The regions included are: Prince Edward Island in Canada; Sicily, Sardinia, Corse, the Greek Archipelago and the Balearic Islands in the Mediterranean Sea; and Åland in Finland.

cluster in neighbouring groups of high-innovative regions versus low-innovative regions and we have to control for the spatial dependence in the models.

Secondly, given the statistically positive result of the Moran's test we searched for which model can better describe the spatial dependence by means of a set of Langrage Multiplier tests on the OLS results. Then, on the grounds of these tests, we used the ML estimator because the OLS would be inefficient in case of spatial correlation. Spatial econometrics provides two empirical ways to incorporate spatial autocorrelation in the model, namely either as a spatially lagged dependent variable (substantive dependence) or in the error term of the regression (nuisance dependence). In order to choose between the two ways, we run two Lagrange Multiplier tests by using the binary contiguity matrix, i.e., the LM-LAG and the LM-ERR. Thus, the specification of the lag model is:

$$logPAT0607_{it} = C_{oit-1}\theta + X_{it-1}\beta + \rho W logPAT06_{it} + \varepsilon_i \quad (6)$$

where $WlogPAT06_{it}$ is the spatially lagged dependent variable for weight matrix W and ρ is the spatial autoregressive coefficient. A positive and significant effect of this coefficient suggests that the knowledge production of region *i* is influenced by knowledge production in neighboring regions. For the error model:

$$logPAT0607_{it} = C_{oit-1}\theta + X_{it-1}\beta + \varepsilon_i \quad (7)$$

with

$$\varepsilon_i = \lambda W \varepsilon_i + u_i \quad (8)$$

where λ is the spatial autoregressive coefficient and u_i is the spherical error term. W is the weight matrix. After running the OLS models and the Lagrange Multiplier tests, we decide to adopt the lag model. The LM tests do not show a remarkable difference between the lag and the error model, but the lag model gives us additional information about the impact of the neighbouring regions' patents through the coefficient *ρ.* For the sake of brevity, we do not display the OLS estimates and LM tests, but they are available upon request.

Exploratory analysis

As preliminary analysis, we look at the maps that refer to the two key independent variables, namely the R&D at home and the R&D offshoring by technological sector. In particular, Figure 1 shows the regions that stay above and below R&D expenditure mean of the whole sample (i.e., *HOME*). All countries have at least one region falling in this category, except Ireland, Greece, South Korea, and some recent EU members (i.e., Czech Republic, Slovakia, and Hungary). In addition, for some European countries (e.g. Italy, Spain, Norway, Sweden, Austria) only the capital region and another highly R&D-intensive region (e.g. Lazio and Lombardy in Italy, and the Comunidad de Madrid and Catalonia in Spain) fall within this category. Moreover, France, the UK and Germany show the highest number of regions with above-average R&D expenditures at home. As far as North America is concerned, only two Canadian provinces in the east of the country belong to this group, namely Ontario and Québec. The twenty-six US states having an above-average R&D at home are mainly located in the Northeast, South and West of the country. The highly R&D-intensive Australian regions are the New South Wales and Victoria, both located nearby the capital region. No South Korean regions perform above average.

[Figure 1, just about here]

Figure 2 represents the distribution of the regions investing in R&D in high technology-intensive sector (i.e., OFF_H). As far the as macro areas are concerned, in Asia/Oceania no investments depart from neither Australia nor South Korea in any of the three sectors. In Europe, few regions offshore R&D activities in high technology-intensive, while Northern American regions are more involved in such investments.

[Figure 2, just about here]

Figure 3 shows regions investing in R&D in medium technology-intensive sectors (i.e., OFF_M). In these sectors, mainly German regions among the European ones and few regions in Northern America are engaged in R&D offshoring investments.

[Figure 3, just about here]

Figure 4 reports regions investing in R&D in knowledge-intensive services sectors (i.e., OFF_{KS}). Few European regions offshore R&D in these sectors, especially in Germany, France, and the UK. In Northern American regions, the distributions of regions in these sectors are more similar to the R&D investment in high technology-intensive (Figure 2) rather than the investments in medium technology-intensive sectors (Figure 4).

[Figure 4, just about here]

Table 2 summarizes some information about the combinations between *HOME* and $OFF_{H,M,KS}$. In particular, the number and percentage of regions falling in each of the eight combinations is reported in the columns 1 and 2, respectively. Moreover, for each of the three sectors the total number of regions doing R&D offshoring is reported (i.e. $OFF_{H,M,KS}$). Columns 3 and 4 present the average number of patents and standard deviation, respectively for each combinative category, as well as for $OFF_{H,M,KS}$. By looking at the distribution of regions across the combinative categories, it is worth noting that the means of patents in the categories in which both complements occur (i.e. $HOMEOFF_{H,M,KS}$) are always higher than in situations where only one of the complements is observed (i.e. $ONLYOFF_{H,M,KS}$ and *ONLYHOME*). This can already be interpreted as a signal of complementarity, suggesting that regions doing both R&D at home and R&D offshoring are also very innovative regions.

[Table 2, just about here]

As an additional exploratory analysis, we look at the unconditional correlations between the complements *HOME* and $OFF_{H,MH,KS}$. We test the null hypothesis of independent pairs of decision variables (Miravete and Pernias, 2006). Table 3 shows the pair-wise Spearman's correlation between *HOME* and $OFF_{H,MH,KS}$. All the coefficients are positive and significant, which is another a signal of complementarity (Cassiman and Veugelers, 2006).

[Table 3, just about here]

8. Econometric results

Table 4 presents the results of the econometric analysis. Columns 1-3 show the results for the model by H, M and KS sectors, respectively. In all models, none of the three explanatory combinative variables (NOHOMEOFF has been dropped due to collinearity[7]) is significant, but ONLYHOME, which is significant at $p \leq 0.01$ for H and at $p \leq 0.05$ for M and KS.

[Table 4, just about here]

The bottom row of Table 4 reports the χ-squared of the complementarity tests for each of the three models and its significance. In the H model, our forecast of absence of complementarity is accepted. In the M model and in the KS model, the absence of complementarity is rejected at the $p \leq 0.05$ and $p \leq 0.10$, respectively. This means that only R&D offshoring in medium technology-intensive and knowledge-intensive services sectors are complementary to the R&D home

[7] 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 ($HOMEOFF_{H,M,KS}$, $ONLYOFF_{H,M,KS}$ and *ONLYHOME*) out of our four categories, according to the following rule:

$$\theta_{11} \quad \theta_{10} \geq \theta_{01} \qquad (5^*),$$

Nonetheless, when NOHOMEOFF is used as the benchmark against the three other dummies, $\theta_{00} = 0$. Accordingly, the inequality tests involving four (Equation 5) or three dummies (Equation 5*), respectively, are equivalent.

expenditures. Thus, when highly R&D-intensive regions perform R&D offshoring in M and KS sectors, their innovation capacity is greater *ceteris paribus* than when the two other conditions apply in isolation. By contrast, although a large part of the regions invest in BRICST in high technology-intensive sectors, this type of R&D offshoring does not have an additional effect on home region knowledge production when performed jointly to outstanding R&D at home.

Robustness checks

Although there are large differences across regions within countries, some similarity might persist at the level of large agglomerations of regions. In particular, European regions might face different cost-opportunities in R&D offshoring in BRICST countries than US regions (Farrell, 2005). In terms of geographical proximity, European regions might prefer offshoring in Eastern European countries (Marin, 2006). Conversely, US regions have a long lasting tradition to invest in South-East Asia and, for geographical proximity, in South-America. Therefore, we want to control whether our results are robust when splitting the sample into two: the US and Western European regions. Results are reported in Table 5.

[Tables 5, just about here]

For the 49 US regions, only R&D offshoring in knowledge-intensive services sectors is complementary in the knowledge production at home ($p \leq 0.01$ level). The sample of 128 European regions replicates the results of the complementarity tests for the M and KS models. Therefore, the robustness checks suggest that our main estimation results are driven by the European regions as far as the M sector is concerned, while both the US and European regions contribute to the results in the KS sector.

Finally, results are robust when calculating *HOME* as equal 1 if *RDhome* is greater than the sample regions' median.

9. Discussion and Conclusion

We began by observing that the global offshoring trend from advanced regions to emerging countries is no longer confined to the offshoring of tangibles. At least parts of R&D activities are now being offshored as well. Based on insights from the economic geography, international business and innovation literatures, we conjectured that complementarity between home region R&D and offshore R&D should obtain when the offshored R&D is dissimilar to the type of (presumably) high-technology R&D carried out in the home region. In other words, we hypothesized that offshore R&D can improve the efficiency of home R&D, when the R&D in the two locations is not of the same technological intensity. When we split the offshore R&D into three categories (high-technology, medium technology and knowledge-intensive services sectors), complementarity only obtain in the cases of medium technology and knowledge-intensive services sectors — not in the case of high technology-intensive sectors. This is in general in line with our theoretical expectations.

This paper contributes to the economic geography and IB literature by being the first paper to systematically address the issue of the effect of offshore R&D in fast-growing emerging economies on the knowledge production in advanced home regions. The traditional economic geography literature still subscribe to the stylized argument that multi-plant firms will tend to locate their information-intensive activities and facilities in knowledge centres, while locating more routinized and standardized activities in more geographically peripheral regions, in order to take account of lower local factor costs (Healey and Watts, 1987; Hayter, 1997). However, more recent economic geography literature has recognized that the spatial behaviour of MNEs has significant implications for regional and local development due to the sheer scale of FDI (McCann and Mudambi, 2005).

Within the geography literature, our results parallel those of Verspagen and Schoenmakers (2004) in the sense that the tendency to perform R&D abroad implies a strengthening of the notion of regional innovation systems, rather than the opposite. Our findings suggest that MNEs invest in knowledge in emerging countries which in turn improves the effectiveness of the production of knowledge in the home region. In this paper, we have suggested that this has to do with specialisation advantages combined with the reverse knowledge transfer from emerging countries within the more general open innovation trend. Our findings also confirm the “systemic” nature of knowledge production underlined in the RSI tradition, although in our case, we addressed the issue of cross-fertilization between region-internal and region-external knowledge. In this regard, our analysis complements the theoretical contribution by Bathelt et al. (2004) in the economic geography literature, who argue for a combination of knowledge-related “local buzz” and “global pipelines” in regional development. Our analysis confirms that regional development (in our case knowledge production) is to some extent dependent on the interaction between knowledge development inside and outside the region. Finally, we think that the contribution found in the present paper lives up to the recent call by McCann and Mudambi (2005) for research that combines insights from the economic geography and international business literatures. In this respect — and as pointed out above — our paper advance traditional economic geography research by challenging the view that more information-intensive activities and facilities are necessarily located in advanced locations. Finally, a contribution is offered to IB research as the study considers the effect of reverse knowledge transfer from home-base augmenting activity in emerging economies.

This study has a number of limitations. The most severe limitation lies in the fact that we are not able to break down home region R&D into different classes associated with different degrees of knowledge intensity. Such a breakdown is currently only possible for offshore R&D. However, such a breakdown will have to await the availability of more detailed R&D statistics at the regional level. A further limitation has to do with the fact that our analysis has been able to address the issue of “in-house” or captive offshoring only. A central challenge to future research in this field concerns the analysis of complementarity/substitutability of outsourced offshore R&D (in addition to captive offshoring). Regardless of the limitations of the present research, we believe that the first analysis presented here have illustrated that the field of research is fertile and that the present paper may serve as a point of departure for future research on the relationship between regional and extra-regional knowledge production.

References

Acs, Z. J., Anselin, L., Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge, *Research Policy*, 31: 1069-1085.

Amin, A., Cohendet, P. (2005). Geographies of Knowledge Formation in Firms, *Industry & Innovation*, 12(4): 465-486.

Andersson, U., Forsgren, M., Holm, U. (2002). The strategic impact of external networks: subsidiary performance and competence development in the multinational corporation, *Strategic Management Journal*, 23: 979-996.

Anselin, L. (1988). *Spatial Econometrics: Methods and Models*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Anselin, L., Varga, A., Acs, Z. (1997). Local geographic spillovers between university research and high technology innovations, *Journal of Urban Economics*, 42: 422–448.

Arora, A., Gambardella, A., Eds. (2005). *From Underdogs to Tigers: The Rise and Growth of the Software Industry in Brazil, China, India, Ireland, and Israel*. Oxford, Oxford University Press.

Arundel, A., Kabla, I. (1998). What percentage of innovations are patented? empirical estimates for European firms, *Research Policy*, 27(2): 127-141.

Asheim, B., Gertler, M. S. (2005). The Geography of Innovation: Regional Innovation Systems. *The Oxford Handbook of Innovation*. J. Fagerberg, D. C. Mowery,R. R. Nelson. Oxford, Oxford University Press**:** 291-317.

Asheim, B. T. (1996). Industrial Districts as 'Learning Regions': A Condition for Prosperity, *European Planning Studies*, 4(4): 379-400.

Athey, S., Stern, S. (1998). An Empirical Framework for Testing Theories About Complementarities in Organizational Design. *NBER Working Paper 6600*.

Athreye, S., Cantwell, J. (2007). Creating competition?: Globalisation and the emergence of new technology producers, *Research Policy*, 36(2): 209-226.

Audretsch, D. B., Feldman, M. P. (1996). R&D Spillovers and the Geography of Innovation and Production, *The American Economic Review*, 86(3): 630-640.

Bathelt, H., Malmberg, A., Maskell, P. (2004). Clusters and Knowledge: Local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography*, 28(1): 31-56.

Beaudry, C., Breschi, S. (2003). Are firms in clusters really more innovative?, *Economics of Innovation and New Technology*, 12(4): 325-342.

Beausang, F. (2004) "Outsourcing and the Internationalization of Innovation." *Working Paper 18*.

Belderbos, R., Sleuwaegen, L. (2007). Intellectual Assets and International Investment: A stocktaking of the evidence. *Report to the OECD Investment Committee DAF/INV/WD(2007)6*. Paris, OECD.

Bode, E. (2004). The spatial pattern of localized R&D spillovers: an empirical investigation for Germany, *Journal of Economic Geography*, 4(1): 43-64.

Braczyk, H.-J., Cooke, P., Heidenreich, M. (1998). *Regional Innovation Systems: The Role of Governance in a globalised World*: Routledge.

Brusoni, S., Prencipe, A. (2001). Unpacking the Black Box of Modularity: Technologies, Products and Organizations *Industrial and Corporate Change*, 10(1): 179-205.

Bulte, C. V. d., Moenaert, R. K. (1998). The Effects of R&D Team Co-location on Communication Patterns among R&D, Marketing, and Manufacturing, *Management Science*, 44(11): S1-S18.

Cantwell, J. (1995). The globalisation of technology: what remains of the product cycle model?, *Cambridge Journal of Economics*, 19(1-4): 155-174.

Cantwell, J., Iammarino, S. (2001). EU Regions and Multinational Corporations: Change, Stability and Strengthening of Technological Comparative Advantages, *Industrial and Corporate Change*, 10(4): 1007-1037.

Cantwell, J., Santangelo, G. D. (1999). The frontier of international technology networks: sourcing abroad the most highly tacit capabilities, *Information Economics and Policy*, 11(1): 101-123.

Cassiman, B., Veugelers, R. (2006). In Search for Complementarity in the Innovation Strategy: Internal R&D and External Knowledge Acquisition, *Management Science*, 52(1): 68-82

Chen, S.-H. (2004). Taiwanese IT firms' offshore R&D in China and the connection with the global innovation network, *Research Policy*, 33(2): 337–349.

Chesbrough, H., Ed. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, Harvard Business School Press.

Cooke, P. (2005). Regionally asymmetric knowledge capabilities and open innovation: Exploring 'Globalisation 2'-A new model of industry organisation, *Research Policy*, 34(8): 1128-1149.

Cooke, P., Uranga, G. M., Etxebarria, G. (1997). Regional innovation systems: Institutional and organisational dimensions, *Research Policy*, 26: 475-491.

Crescenzi, R., Rodriguez-Pose, A., Storper, M. (2007). The territorial dynamics of innovation: a Europe United States comparative analysis, *Journal of Economic Geography*, 7: 673-709.

Doh, J. P. (2005). Offshore Outsourcing: Implications for International Business and Strategic Management Theory and Practice, *Journal of Management Studies*, 42(3).

Dunning, J. (1977). Trade, Location of Economic Activity and the Multinational Enterprise. *The International Allocation of Economic Activity*. B. Ohlin, P.-O. Hesselborn,P. M. Wijkman. London, Macmillan**:** 395-418.

EUROSTAT (2006). High-technology manufacturing and knowledge-intensive services sectors. Luxembourg, EUROSTAT.

Farrell, D. (2005). Offshoring: Value creation through economic change, *Journal of Management Studies*, 42(3): 675-683.

Feldman, M. P. (1994). Knowledge complementarity and innovation, *Small Business Economics*, 6: 363-372.

Feldman, M. P. (2003). The Locational Dynamics of the US Biotech Industry: Knowledge Externalities and the Anchor Hypothesis, *Industry & Innovation*, 10(3): 3111-3329.

Forsgren, M., Holm, U., Johanson, J. (2005). *Managing the Embedded Multinational – A Business Network View.* . Cheltenham: Edward Elgar.

Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Pinter.

Frenken, K., Van Oort, F., Verburg, T. (2007). Related Variety, Unrelated Variety and Regional Economic Growth, *Regional Studies*, 41(5): 685-697.

Gertler, M. S. (2003). Tacit knowledge and the economic geography of context, or The undefinable tacitness of being (there), *Journal of Economic Geography*, 3(1): 75-99.

Ghoshal, S., Korine, H., Szulanski, G. (1994). Interunit communication in multinational corporations, *Management Science*, 40(1): 96-110.

Giuri, P., Torrisi, S., Zinovyeva, N. (2008). ICT, skills, and organizational change: evidence from Italian manufacturing firms, *Industrial and Corporate Change*, 17(1): 29-64.

Hatzichronoglou, T. (1997). Revision of the High-Technology Sector and Product Classification. Paris, OECD Publishing.

Hayter, R. (1997). *The dynamics of industrial location: The factory, the firm and the production system*. Chichester: John Wiley and Sons.

Healey, M., Watts, H. D. (1987). The multiplant enterprise. *Industrial change in the United Kingdom*. W. F. Lever. Harlow, Longman.

Howells, J. (1995). Going global: The use of ICT networks in research and development, *Research Policy*, 24(2): 169–184.

Howells, J. (1999). Regional systems of Innovation? Innovation policy in a global economy. *Innovation Policy in a Global Economy*. D. Archibugi, J. Howells,J. Michie, Cambridge University Press: 67-93.

Iammarino, S., McCann, P. (2006). The structure and evolution of industrial clusters: Transactions, technology and knowledge spillovers, *Research Policy*, 35: 1018-1036.

Jaffe, A. (1986). Technological Opportunity and Spillovers of R & D: Evidence from Firms' Patents, Profits, and Market Value, *The American Economic Review*, 76(5): 984-1001.

Jaffe, A., Trajtenberg, M., Henderson, R. (1993). Geographic localization of knowledge spillover as evidenced by patent citations, *The Quarterly Journal of Economics*, 108(3): 577-598.

Kedia, B. L., Mukherjee, D. (2008). Understanding offshoring: A research framework based on disintegration, location and externalization advantages, *Journal of World Business*, 44(3): 250-261

Keeble, D., Lawson, C., Moore, B., et al. (1999). Collective learning process, networking and institutional thickness in the Cambridge Region, *Regional Studies*, 33(4): 319-322.

Khan, M., Dernis, H. (2006) "Global Overview of Innovative Activities from the Patent Indicators Perspective." *OECD Science, Technology and Industry Working Papers, 2006/3*.

Kogut, B. (1985). Designing global strategies: comparative and competitive value added chains, *Sloan Management Review*, 26(4): 15-28.

Kotabe, M. (1990). The relationship between offshore sourcing and innovativeness of U.S. multinational firms: an empirical investigation, *Journal of International Business Studies*, 4: 623-638.

Kotabe, M., Murray, J. Y. (2003). Global Sourcing Strategy and Sustainable Competitive Advantage, *Industrial Marketing Management*, 33(1): 7-14.

Kotabe, M., Parente, R., Murray, J. Y. (2007). Antecedents and outcomes of modular production in the Brazilian automobile industry: a grounded theory approach, *Journal of International Business Studies*, 38(1): 84–106.

Lall, S. (2003). Indicators of the relative importance of IPRs in developing countries, *Research Policy*, 32(9): 1657-1680.

Le Bas, C., Sierra, C. (2002). Location versus home country advantages' in R&D activities: some further results on multinationals' locational strategies, *Research Policy*, 31(4): 589-609

Lehto, E. (2007). Regional Impact of Research and Development on Productivity, *Regional Studies*, 41(5): 623–638.

Lewin, A. Y., Massini, S., Peeters, C. (2009). Why Are Companies Offshoring Innovation? The Emerging Global Race for Talent, *Journal of International Business Studies*, 40(6): 901-925.

Lundvall, B.-Å. (1992). *National systems of innovation: towards a theory of innovation and interactive learning*. London: Pinter.

Manning, S., Massini, S., Lewin, A. Y. (2008). A Dynamic Perspective on Next-Generation Offshoring: The Global Sourcing of Science and Engineering Talent, *Academy of Management Perspectives*, 22(3): 35-54.

Mansfield, E., Romeo, A. (1984). Reverse transfers of technology from overseas subsidiaries to American firms, *IEEE Transactions on Engineering Management*, EM-31, August(122-27).

Maraut, S., Dernis, H., Webb, C., et al. (2008) "The OECD REGPAT Database: A Presentation." *OECD Science, Technology and Industry Working Papers* 2008/2 DOI: 10.1787/241437144144.

Marin, D. (2006). A New International Division of Labor in Europe: Outsourcing and Offshoring to Eastern Europe, *Journal of the European Economic Association*, 4(2-3): 612-622.

McCann, P., Mudambi, R. (2005). Analytical differences in the economics of geography: the case of the multinational firm, *Environment and Planning A*, 37(10): 1857-1876.

Milgrom, P., Roberts, J. (1990). Rationalizability, Learning, and Equilibrium in Games with Strategic Complementarities, *Econometrica*, 58(6): 1255-1277.

Milgrom, P., Roberts, J. (1995). Complementarities and fit strategy, structure, and organizational change in manufacturing, *Journal of Accounting and Economics*, 19(2-3): 179-208.

Miravete, E., Pernias, J. (2006). Innovation complementarity and scale of production, *Journal of Industrial Economics*, 54(1): 1-29.

Moreno, R., Paci, R., Usai, S. (2005). Spatial spillovers and innovation activity in European regions, *Environment and Planning*, 37: 1793-1812.

Morgan, K. (2004). The exaggerated death of geography: learning, proximity and territorial innovation systems, *Journal of Economic Geography*, 4(1): 3-21.

Mudambi, R. (2008). Location, control and innovation in knowledge-intensive industries, *Journal of Economic Geography*, 8: 699-725.

Mudambi, R., Navarra, P. (2004). Is knowledge power? Knowledge flows, subsidiary power and rent-seeking within MNCs, *Journal of International Business Studies*, 35: 385-406.

Narula, R., Hagedoorn, J. (1999). Innovating through strategic alliances: moving towards international partnerships and contractual agreements, *Technovation*, 19.

Nelson, R. R. (1993). *National innovation systems: a comparative study*. New York: O.U.P.

Ó hUallacháin, B., Leslie, T. F. (2007). Rethinking the regional knowledge production function, *Journal of Economic Geography*, 7: 737–752.

OECD (2008). Territorial Grid of OECD Member Countries, OECD Public Governance and Territorial Development Directorate.

Paci, R., Usai, S. (2009). Knowledge flows across European regions. , *The Annals of Regional Science*, 43(3): 669-690.

Patel, P., Vega, M. (1999). Patterns of internationalisation of corporate technology: location vs. home country advantages, *Research Policy*, 28(2/3): 145-155.

Porter, M. E. (1990). *The Competitive advantage of nations*. New York: Free Press.

Quinn, J. B. (1992). *Intelligent enterprise: A knowledge and service based paradigm for industry*. New York: Free Press.

Ramamurti, R. (2004). Developing countries and MNEs: Extending and enriching the research agenda, *Journal of International Business Studies*, 35(4): 277-283.

Rodríguez-Pose, A., Crescenzi, R. (2008). Research and Development, Spillovers, Innovation Systems, and the Genesis of Regional Growth in Europe, *Regional Studies*, 42(1): 51–67.

Scherer, F. M. (1983). The propensity to patent, *International Journal of Industrial Organization*, 1(1): 107-128.

Schmoch, U. (2008) "Conception of a Technology Classification for Country Comparisons."

Sterlacchini, A. (2008). R&D, higher education and regional growth: Uneven linkages among European regions, *Research Policy*, 37(6-7): 1096-1107.

Stopford, J. J., Wells, L. T. (1972). *Managing the Multinational Organisation of the Firm and Overlap of Subsidiaries*. New York: Basic Books.

Tan, J. (2006). Growth of industry clusters and innovation: Lessons from Beijing Zhongguancun Science Park, *Journal of Business Venturing*, 21(6): 827-850.

Teece, D. J. (1987). Capturing value from technological innovation: Integration, strategic partnering, and licensing decisions. *Technology and global industry*. B. R. Guile,H. Brooks. Washington, D.C, National Academy Press.

Trefler, D. (2005). Service Offshoring: Threats and Opportunities, *In Brookings Trade Forum*, 2005: 35-73.

UNCTAD (2005). World Investment Report. TNCs and the Internationalization of R&D. Geneva, United Nations.

Usai, S. (2008) "The Geography of Inventive Activities in OECD Regions." *STI Working Paper 2008/3*.

Verspagen, B., Schoenmakers, W. (2004). The spatial dimension of patenting by multinational firms in Europe, *Journal of Economic Geography*, 4(1): 23-42.

von Hippel, E. (1988). *The Sources of Innovation*. New York: Oxford University Press.

Zhao, M. (2006). Conducting R&D in Countries with Weak Intellectual Property Rights Protection, *Management Science*, 52(8): 1185-1199.

Figure 1 –OECD regions standing above and below R&D expenditures mean

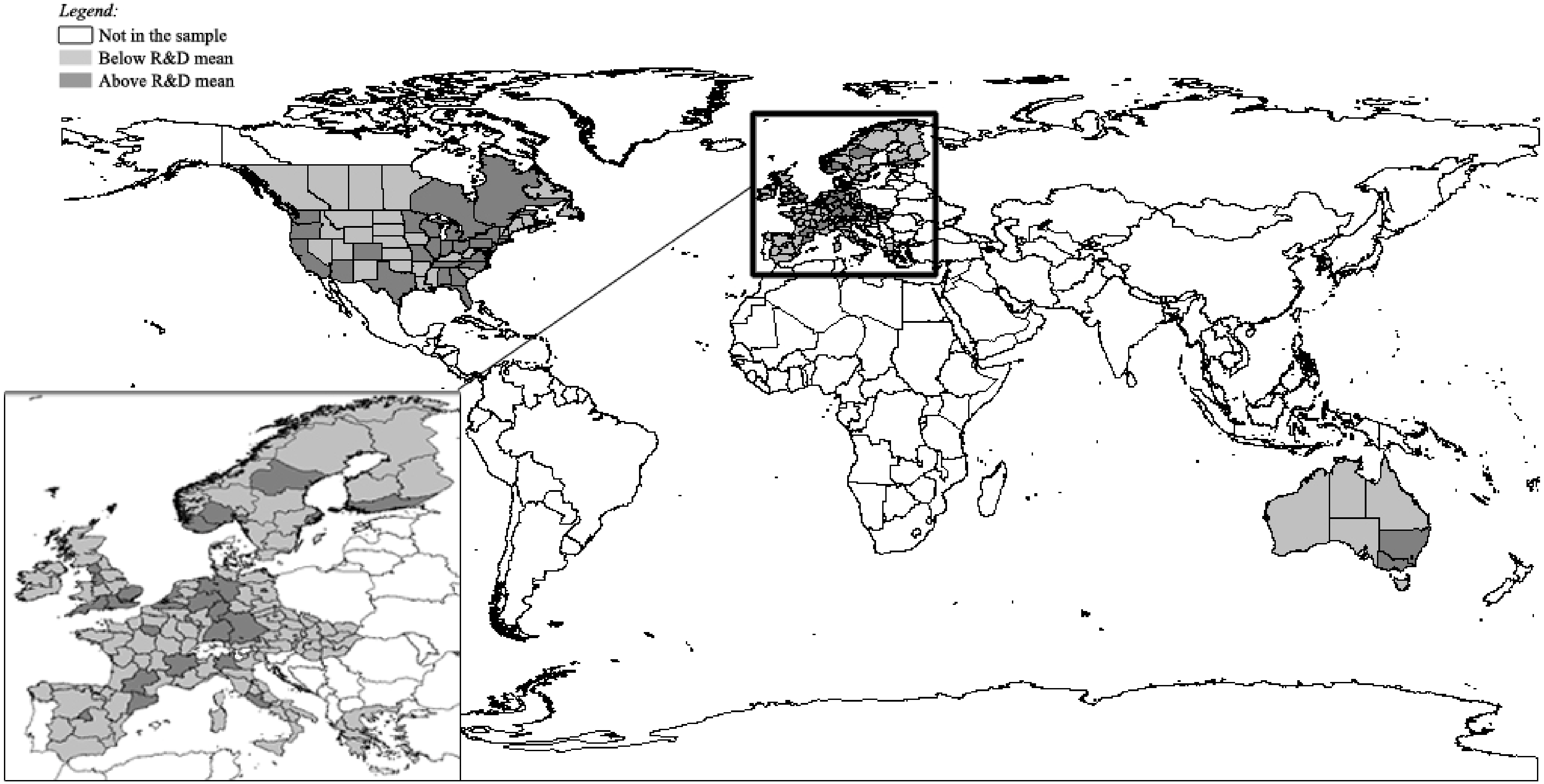

Figure 2 –OECD regions from which R&D offshoring investments in high technology-intensive sectors depart

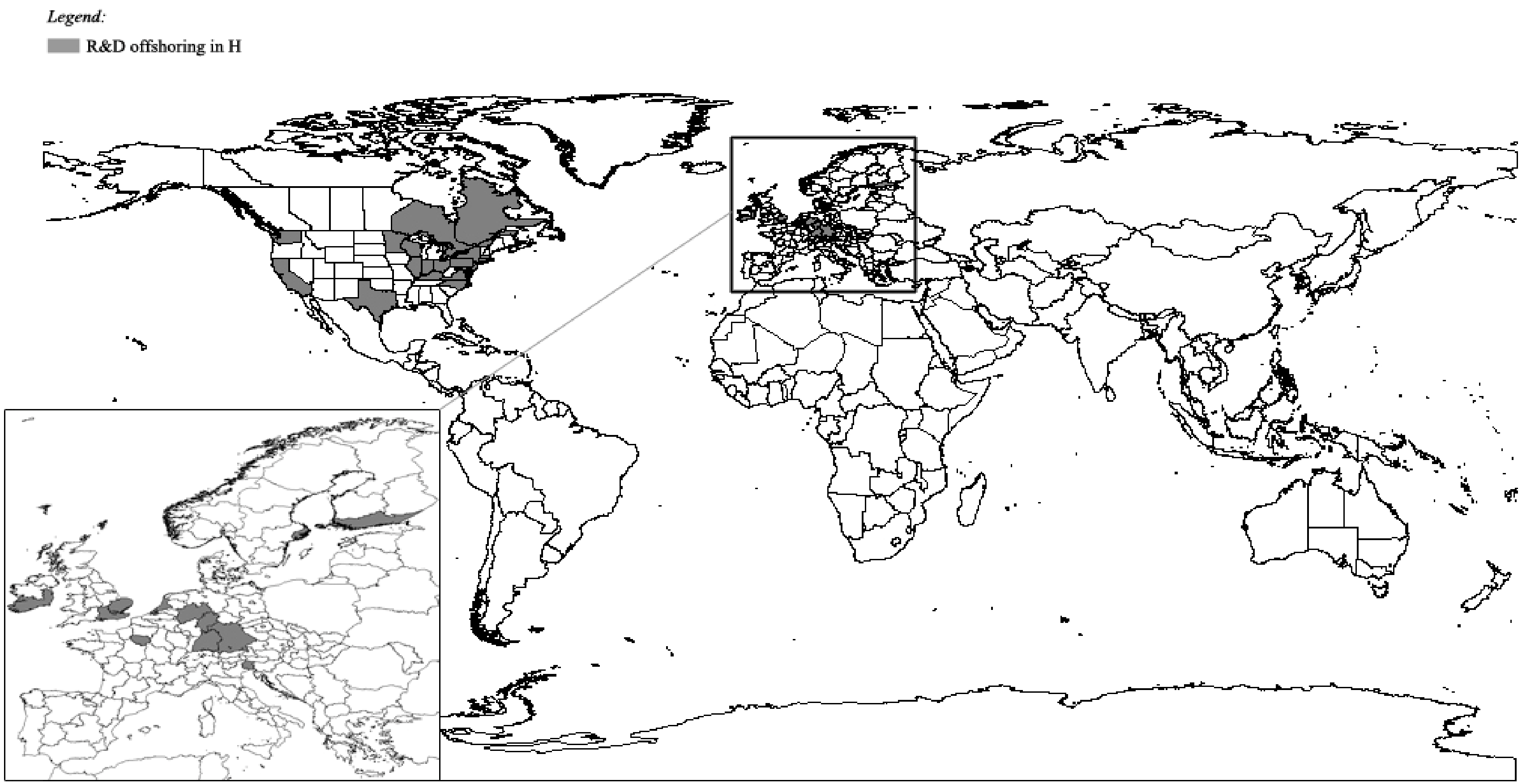

Figure 3 – OECD regions from which R&D offshoring investments in medium technology-intensive sectors depart

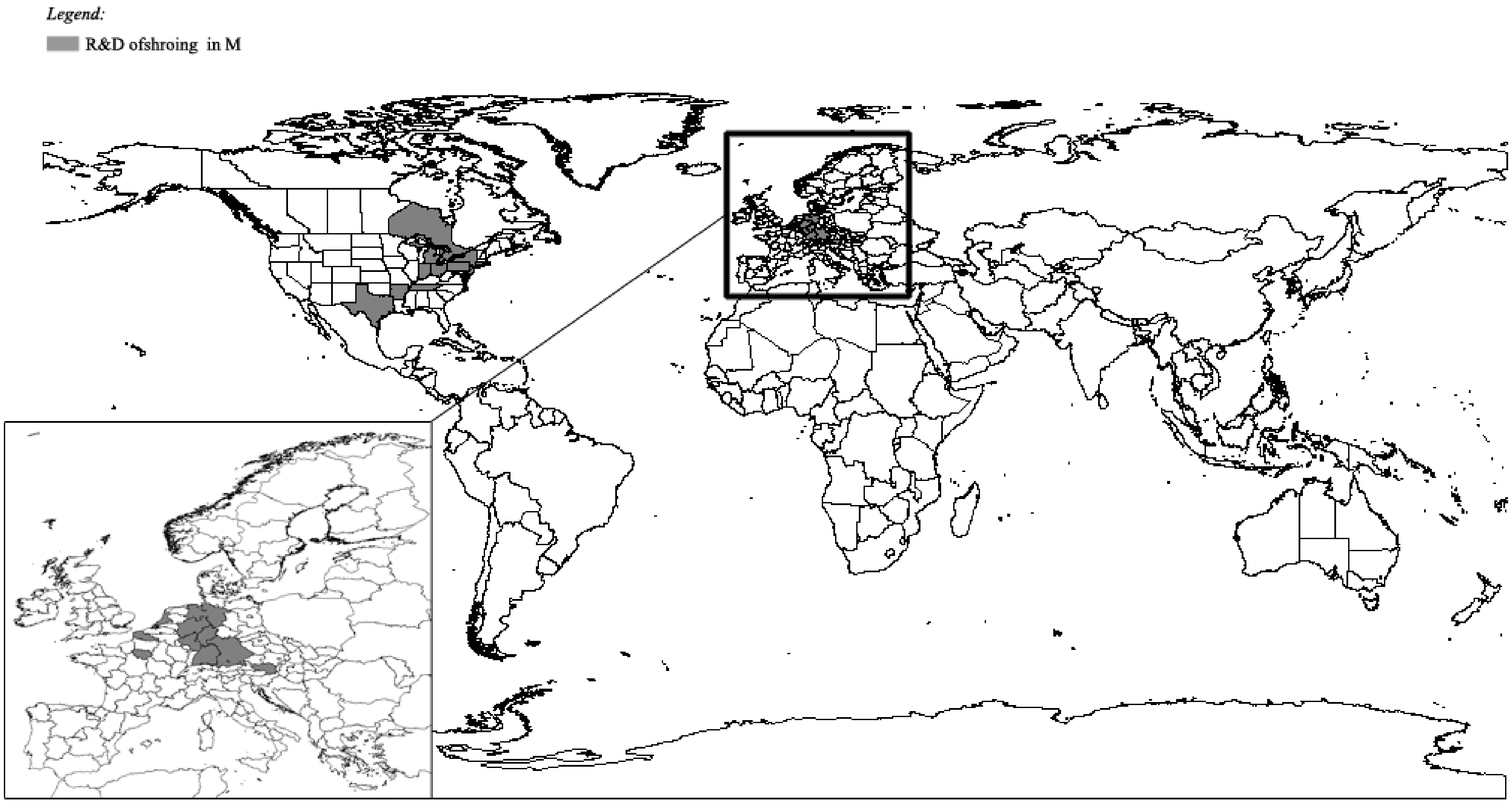

Figure 4 – OECD regions from which R&D offshoring investments in knowledge-intensive services sectors depart

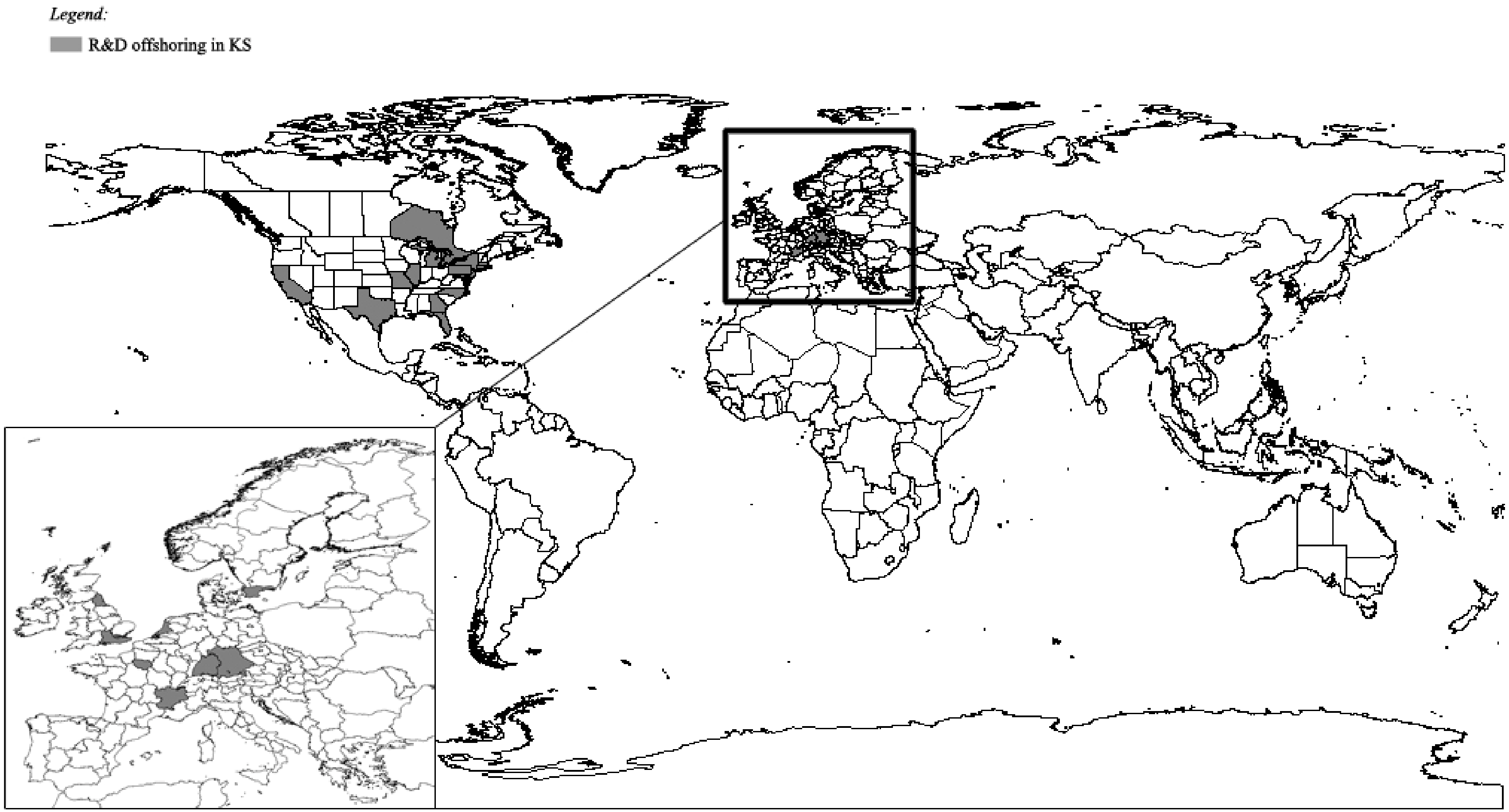

Table 1– fDi Market, OECD and EUROSTAT sectoral breakdowns, and the sectoral aggregation adopted

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

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

Table 2 – Distribution of regions and patents

	No.	*%*	*Mean Patents*	*Std. Dev.*
High				
HOMEOFF_H	29	13%	2205.2	395.6
ONLYOFF_H	4	2%	1251.0	1063.0
OFF_H=1	***33***	***15%***	***2089.5***	***369.0***
Medium				
HOMEOFF_M	19	9%	1946.9	306.1
ONLYOFF_M	7	3%	920.3	601.7
OFF_M=1	***26***	***12%***	***1670.5***	***284.6***
Knowledge-intensive services				
HOMEOFF_KS	23	10%	2393.6	485.4
ONLYOFF_KS	3	1%	319.2	173.9
OFF_{KS}=1	***26***	***12%***	***2154.2***	***448.7***
ONLYHOME	20	9%	463.7	63.5
NOHOMEOFF	151	68%	150.3	18.2

Table 3 – Spearman's correlation

	HOME
OFF_H	0.5946*
OFF_M	0.3947*
OFF_{KS}	0.5231*

* p≤0.001.

Table 4 – Econometric results

	Model 1			Model 2			Model 3		
	H			M			KS		
Dep. Variable	logPAT0607			logPAT0607			logPAT0607		
Explanatory	Coef.		St. Err.	Coef.		St. Err.	Coef.		St. Err.
ONLYHOME	0.604	***	0.204	0.458	**	0.206	0.460	**	0.200
HOMEOFF_H	0.422		0.404						
ONLYOFF_H	-0.406		0.570						
HOMEOFF_M				-0.832		0.544			
ONLYOFF_M				-0.202		0.656			
HOMEOFF_KS							-0.483		0.725
ONLYOFF_KS							0.030		0.823
Controls									
DEN	0.000		0.000	0.000		0.000	0.000		0.000
CAP	-0.115		0.276	0.205		0.259	0.222		0.274
FIN_SHARE	0.132	***	0.047	0.169	***	0.048	0.163	***	0.046
INTERNATCOOP	-0.052	***	0.008	-0.053	***	0.008	-0.052	***	0.008
HK_SHARE	0.021	***	0.007	0.023	***	0.007	0.022	***	0.007
POP	0.000	***	0.000	0.000	***	0.000	0.000	***	0.000
VAL_H	-0.002	**	0.001						
VAL_M				0.005	**	0.002			
VAL_{KS}							-0.000		0.006
FDI_D	-0.465	***	0.167	-0.515	***	0.174	-0.476	***	0.167
adjRTA1	1.042	***	0.327	0.975	***	0.340	0.930	***	0.330
adjRTA2	0.525	**	0.260	0.648	**	0.269	0.596	**	0.259
adjRTA3	0.578		0.367	0.454		0.379	0.362		0.369
adjRTA4	-0.364		0.394	-0.518		0.414	-0.342		0.400
$BR_{H,M,KS}$	-0.017		0.655	0.058		0.744	0.059		6.714
$CN_{H,M,KS}$	0.826	**	0.381	-0.023		0.526	0.537		0.804
$IN_{H,M,KS}$	0.509		0.349	0.565		0.435	0.893		0.732
$RU_{H,M,KS}$	0.738		0.718	0.079		0.456	-2.583	**	1.242
$SG_{H,M,KS}$	-0.775	**	0.363	0.765		0.554	-0.823		0.601
$TW_{H,M,KS}$	-0.025		0.379				-0.294		1.061
WESTEUROPE	0.142		0.208	0.142		0.215	0.133		0.208
NORTHAMERICA	-0.749	***	0.280	-0.743	**	0.291	-0.798	***	0.280
_cons	3.333	***	0.304	3.229	***	0.316	3.120	***	0.306
rho _cons	0.039	***	0.005	0.043	***	0.006	0.042	***	0.006
sigma _cons	0.799	***	0.038	0.827	***	0.039	0.801	***	0.038
Number of obs.	*221*			*221*			*221*		
				TEST of COMPLEMENTARITY					
chi2	0.16			4.09**			2.81*		

*** p□.01; ** p□.05; * p□.10.

Table 5 – Robustness checks for the United States and for European regions

	United States						*Western Europe*					
	Model 4		**Model 5**		**Model 6**		**Model 7**		**Model 8**		**Model 9**	
	H		**M**		**KS**		**H**		**M**		**KS**	
Dep. Variable	logPAT0607		logPAT0607		logPAT0607		logPAT0607		logPAT0607		logPAT0607	
Explanatory	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.
ONLYHOME	0.586 *	0.302	0.335	0.355	0.166	0.313	0.496 **	0.250	0.201	0.247	0.374	0.245
HOMEOFF_H	0.889 **	0.433					0.531	0.788				
ONLYOFF_H	-0.390	0.758					-0.224	0.973				
HOMEOFF_M			-0.149	0.895					-0.270	1.301		
ONLYOFF_M			-0.965	1.059					1.255	1.299		
HOMEOFF_KS					-1.166	0.876					1.324	1.435
ONLYOFF_KS					-4.072 ***	1.059					2.665 *	1.609
Controls												
DEN	0.001	0.001	0.001	0.001	0.006 ***	0.001	0.000	0.000	0.000	0.000	0.000	0.000
CAP	-7.385 *	4.395	-7.099	5.072	-23.08 ***	6.729	0.128	0.382	0.826 **	0.333	0.677 *	0.359
FIN_SHARE	0.095	0.087	-0.027	0.133	0.116	0.086	0.077	0.076	0.046	0.074	0.071	0.075
INTERNATCOOP	-0.035	0.051	-0.063	0.064	-0.092 *	0.053	-0.055 ***	0.013	-0.054 ***	0.013	-0.058 ***	0.013
HK_SHARE	0.082 ***	0.030	0.107 ***	0.036	0.064 **	0.029	0.012	0.010	0.017 *	0.010	0.015	0.010
POP	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000	0.000 ***	0.000
VAL_H	-0.001	0.001					-0.002	0.004				
VAL_M			0.000	0.008					0.005	0.003		
VAL_{KS}					0.004	0.006					0.007	0.013
FDI_D							-0.338 **	0.168	-0.476 ***	0.169	-0.398 **	0.174
adjRTA1	-1.166	0.744	-0.688	0.938	-1.077	0.747	1.082 ***	0.407	1.136 ***	0.415	1.108 ***	0.430
adjRTA2	-0.892	0.696	0.579	0.877	0.014	0.656	0.797 **	0.330	0.800 **	0.335	0.837 **	0.342
adjRTA3	-2.677 ***	0.918	-1.774	1.152	-3.046 ***	0.914	0.875 *	0.457	0.570	0.473	0.755	0.485
adjRTA4	0.170	0.614	-0.227	0.730	-0.571	0.650	-0.398	0.529	-0.111	0.548	-0.227	0.555
$BR_{H,M,KS}$					-6.451	6.802	0.595	0.900	-1.643 *	0.920		
$CN_{H,M,KS}$	0.174	0.456	1.897	1.547	-1.275	0.848	1.870 **	0.815	-0.613	1.177	-1.289	1.779
$IN_{H,M,KS}$	0.387	0.377	-0.004	0.842	1.319	0.935	-0.703	0.670	-2.023 **	0.972	-1.604	1.616
$RU_{H,M,KS}$	0.534	1.718	0.964	0.861	-0.933	0.847	1.431	1.340	-2.355	1.554		
$SG_{H,M,KS}$	-1.382 ***	0.496	0.389	1.363			-1.480 **	0.700	1.750	1.243	0.387	1.084
$TW_{H,M,KS}$	0.361	0.469	0.870	1.351	-1.209	0.842	0.018	0.855				
_cons	1.626 **	0.787	1.882 *	0.982	2.418 ***	0.796	3.505 ***	0.368	3.344 ***	0.379	3.533 ***	0.374
rho _con	0.025 **	0.010	0.026 **	0.011	0.006	0.009	0.056 ***	0.007	0.055 ***	0.008	0.054 ***	0.007
sigma _con	0.508 ***	0.051	0.617 ***	0.046	0.501 ***	0.050	0.751 ***	0.046	0.760 ***	0.047	0.784 ***	0.049
Number of obs.	*49*		*49*		*49*		*128*		*128*		*128*	
					TEST of COMPLEMENTARITY							
chi2	0.88		0.26		10.35***		0.81		5.41**		3.97**	

*** p□.01; ** p□.05; * p□.10.

Table A1 – Variable Definitions and descriptive statistics

Variable	Description	Source	Period	Mean	Std. Dev.
PAT0607	PCT applications which have designed EPO at the international phase by inventor's residence and fractional count. 2-year average. Log-transformed (*logPAT0607*)	REGPAT	2006-2007	502.06	1084.69
FIN_SHARE	Share of employment in financial intermediation	RDB	2004 (1)	3.01	1.64
INTERNATCOOP	Share of patents with multiple inventors in which at least one inventor is not resident in the same country of region *i*	REGPAT	2003-2005	25.31	44.98
HK_SHARE	Share of population with tertiary education (ISCED 5 - 6)	RDB	2003-2005	24.06	8.73
POP	Regional population	RDB	2003-2005	3,564,117	4,320,656
VAL_H	Sum of the value of R&D investments departing from region *i* in sector H (million US dollars)	fDi Market	2003-2005	25.77	109.14
VAL_M	Sum of the value of R&D investments departing from region *i* in sector M (million US dollars)	fDi Market	2003-2005	10.15	42.40
VAL_{KS}	Sum of the value of R&D investments departing from region *i* in sector KS (million US dollars)	fDi Market	2003-2005	12.47	94.43
FDI_D	Dummy, 1 for positive net FDI inward stock (country level)	UNCTAD	2003-2005		
$adjRTA_1$	Index of Reveal Technological Advantage of Electrical Engineering technological group	REGPAT	2003-2005	-0.24	0.27
$adjRTA_2$	Index of Reveal Technological Advantage of Instruments technological group	REGPAT	2003-2005	-0.10	0.23
$adjRTA_3$	Index of Reveal Technological Advantage of Chemistry technological group	REGPAT	2003-2005	-0.03	0.21
$adjRTA_4$	Index of Reveal Technological Advantage of Mechanical Engineering technological group	REGPAT	2003-2005	0.08	0.23
$adjRTA_5$	Index of Reveal Technological Advantage of Other Fields technological group	REGPAT	2003-2005	0.10	0.31
DEN	Regional population density	RDB	2003-2005		
CAP	Dummy, 1 if the region hosts the country capital city	RDB	2003-2005		
$BR_{H,M,KS}$, $RU_{H,M,KS}$, $IN_{H,M,KS}$, $CN_{H,M,KS}$, $SG_{H,M,KS}$, $TW_{H,M,KS}$	Dummy for destination countries of R&D investments by sector H, M, and KS. Respectively, Brazil, Russia, India, China, Singapore, and Taiwan.	fDi Market	2003-2005		
NORTHAMERICA	Dummy for investing countries Canada and the US.	fDi Market	2003-2005		
WESTEUROPE	Dummy for investing countries EU15 and Norway. Excluded from OECD European countries: Hungary, Czech Republic and Slovakia.	fDi Market	2003-2005		

(1) For Germany, the available year is 2003.