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Does R&D offshoring displace or strengthen knowledge production at home? Evidence from OECD countries

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Introduction

This chapter aims to investigate whether offshoring of R&D activity in fast-growing economies impacts on the knowledge creation of home investing countries. This research question goes back to the debate on whether these investments really strengthen home countries' knowledge production (Hemphill, 2005; Kotabe, 1990), or instead they hasten a possible hollowing out and/or a polarization of a home country's competences (Bardhan and Jaffee, 2005; Lieberman, 2004; Teece, 1987). Despite further research conducted on this issue (e.g., Egger *et al.*, 2001; Falk and Wolfmayr, 2005; Feenstra and Hanson, 1999; Gersbach and Schmutzler, 2006; Hansson, 2005; Hsieh and Woo, 2005; Naghavi and Ottaviano, 2009), consensus on the net impact of offshoring on the home country is lacking and additional empirical evidence is needed.

Available statistics clearly document an increasing degree of R&D internationalization by multinational firms as well as a recent change in the location and nature of their overseas activities (Belderbos and Sleuwagen, 2007; UNCTAD, 2005). Specifically, both UNCTAD and OECD data show that Singapore, India, China, Korea, and, to a lesser extent, Brazil are increasingly attracting R&D by multinationals. In particular, UNCTAD estimates that of the 1,773 FDI projects involving R&D as a key business function during 2002–04, no fewer than 1,095 went to Eastern Europe and Asia, with India and China the most important destination countries (UNCTAD, 2005: xxvi). Official statistics for China mention that this country hosted some 750

foreign R&D centers, most of these established after 2001; for India it was estimated that by the end of 2004, over 100 multinational enterprises (MNEs) had established R&D centers (UNCTAD, 2005). Other recent surveys among MNEs on R&D investment plans more clearly suggest that China, India, Singapore, and, to a lesser extent, Brazil, are among the top ten of R&D investment locations behind the US and the UK. However, although offshoring poses challenges to strategic management research in understanding the development and deployment of firm-level capabilities (Doh, 2005), international business (IB) research has paid limited attention to this phenomenon. In addition, Doh and Pearce (2003) contend that theories of internationalization (e.g., Johanson and Vahlne, 1990; Vernon, 1966) and FDI (e.g., Dunning, 1977) have failed to adequately incorporate the distinctive nature of services and intangible activities which are those more increasingly sited offshore.

This study seeks to fill this gap by means of an exploratory cross-country analysis focusing on OECD countries investing in BRICKST (Brazil, Russia, India, China, Korea, Singapore, and Taiwan). Within this context, we test whether R&D offshore in BRICKST complements/substitutes knowledge production at home and whether and how it affects the sectoral focus/mix of knowledge production. To this end, we use the knowledge production function framework (e.g., Griliches, 1979), which suggests that the output of knowledge depends on two inputs: (i) domestic investments in R&D, and (ii) R&D conducted abroad. Bearing in mind the limitations of the macro approach adopted, our findings suggest a positive impact of R&D offshore in BRICKST on the knowledge production of home OECD investing countries. Moreover, knowledge production at home seems to benefit from both domestic R&D as well as from R&D activities offshore in BRICKST as far as high-technology sectors are concerned. Instead, in medium- and low-technology sectors OECD countries' knowledge production at home is only fed by innovative activity offshore in BRICKST.

Theoretical framework and hypotheses

Despite the increasing interest in the offshoring phenomenon, a commonly shared definition of offshoring is still missing. A primary distinction made by UNCTAD (2004) concerned offshoring activities done internally within companies through the establishment of foreign

subsidiaries (i.e., captive offshoring) and offshoring activities done externally through outsourcing a service to a third-party provider (i.e., offshore outsourcing). In this chapter, we will use the term “offshoring” in general although focusing on captive offshoring only. Along the lines of recent studies (Bunyaratavej *et al.*, 2007; Venkatraman, 2004), we then define international offshoring as the practice of placing activities at offshore locations outside the investing home country. Our definition does not necessarily imply that those activities are not carried out any longer in the home investing country once the offshore decision has been taken. In other words, the relocation of activities in other countries may well co-exist with the persistence of the same type of activities at home. We, therefore, use the term offshoring as interchangeable with internationalization.

We intend to capture the fact that offshoring *per se* has been a long-lasting phenomenon in the IB literature and does not represent something new. The international localization of manufacturing work and blue-collar jobs is indeed a long-lasting strategy. However, thanks to the fast pace of technological developments, companies have been able to increasingly create value by globally dispersing individual activities where they can be most efficiently executed (Zaheer and Manrakhan, 2001; Zaheer and Zaheer, 2001). Thus, what is new about the phenomenon at hand is the growing location abroad of a series of white-collar business processes that until a few decades ago could be executed only at home (Dossani and Kenney, 2006). The activities internationally offshore have over time climbed back up the value chain with manufacturing activities being offshore in the 1980s, IT departments in the 1990s and a range of other services relating to accounting, human resources management, finance, sales, and after-sales in the following decade. What, however, is nowadays raising many concerns is the increased offshoring of innovative activity in fast-growing emerging countries such as BRICKST. Offshoring is no longer limited to standardized IT or business processes, but increasingly involves new product development activities, R&D, and new product design (Engardio and Einhorn, 2005; Maskell *et al.*, 2006; Patel and Vega, 1999; Subramaniam and Venkatraman, 2001). Western countries and developed market economies in general fear that they stand to lose their comparative advantage in knowledge-intensive products as new countries emerge with the basic capabilities needed to provide some technology-based services. This phenomenon has been amplified by the shift from traditional competence exploiting

(home base exploiting) foreign R&D activities – where MNEs undertake, outside their countries of origin, adaptation and modification of existing technological assets, to local demand conditions – to the competence creating (home base augmenting) ones, where MNEs “tap into” local technical and scientific infrastructures (Ambos, 2005; Cantwell and Mudambi, 2005; Kuemmerle, 1999). Accordingly, unlike the concentration in knowledge production recorded until a decade ago (Kumar and Russell, 2002), a significant proportion of MNEs’ R&D has moved to the countries of developing Asia (Lewin and Couto, 2006), which have emerged as new technology producers (Athreye and Cantwell, 2007), and in particular in BRICKST.

The increase in cross-border knowledge flows involves both technology transfer from headquarters to foreign subsidiaries and “reverse” technology transfer from foreign R&D units to domestic operations, as well as technological transfer between subsidiaries (Håkanson and Nobel, 2001). Theory and evidence on MNEs (Almeida, 1996; Cantwell, 1995; Dunning, 1998; UNCTAD, 2001, 2005) has traditionally acknowledged that FDI are more and more selectively tapping knowledge in specific host markets when designing their global knowledge sourcing strategies. Due to the immobility and partially tacit nature of knowledge, its transfer requires frequent interactions (Kogut and Zander, 1992). Accordingly, the “technology-seeking” or “knowledge-seeking” argument contends that firms may expand abroad in search of capabilities complementary to those available in their home markets and recognizes that home-country knowledge production provides the necessary absorptive capacity (Cantwell, 1989). This suggests that firms also use knowledge-seeking investments to source technical diversity (Chung and Alcácer, 2002). Recent research on offshoring has highlighted the significance of strategic determinants of offshoring decisions (Quinn and Hilmer, 1994) such as educational and cultural levels as reflected in higher wages (Bunyaratavej *et al.*, 2007). Patel and Vega (1999) demonstrate empirically that companies invest abroad in core innovative areas where they are strong at home, suggesting that R&D offshoring decisions are hardly intended to compensate for technological weakness at home, but rather to further enhance home-country technological advantage. Hence, the hollowing out concern is just one side of the coin since knowledge developed in offshore locations can be transferred back to home investing countries where it can feed knowledge production. In line with the knowledge-seeking argument, we then pose that

H1: R&D offshore in BRICKST positively impacts on the knowledge production of the home investing country.

However, sectoral differences in the geography of knowledge production have been detected and explained mainly in terms of degree of knowledge tacitness and complexity (Cantwell and Santangelo, 1999, 2000). In that, innovative activity involving highly tacit and complex knowledge are geographically concentrated at home, while the development of more codifiable knowledge is more locationally dispersed. In this sense, offshoring suggests a complete decoupling of factors across geographic space with more tacit and complex innovative activities carried out in advanced economies, and more routinized and standardized activities offshore (Mudambi, 2008). This international division of labor in knowledge production has then favored the rise of a market for technologies (Arora and Gambardella, 2001) with more complex high-tech knowledge produced in developed countries and more standardized medium- and low-tech knowledge generated in developing countries and eventually transferred and traded across countries. This pattern is closely associated with the modularization of technology (Chesbrough and Kusunoki, 2001) which allows the firms to focus on activities associated to highest value-added in order to source abroad other activities associated with lower value-added more cheaply and efficiently (Ernst and Lim, 2002).

Accordingly, Hirshfeld and Schmid (2005) argue that, although firms in the US and Europe are increasingly attracted to emerging countries, advanced economies are likely to remain at the forefront of innovation activities in high-tech more advanced sectors, at least in the foreseeable future (Ernst, 2006; Lewin *et al.*, 2009; Manning *et al.*, 2008). The production of high-tech knowledge in developed countries is indeed fed by domestic technological capabilities as well as by medium- and low-tech knowledge generated abroad as a result of the modular character of technology (Chesbrough and Kusunoki, 2001). This is in line with results already obtained in the eighties by Mansfield and Romeo (1984) who documented the increased significance of complementary R&D activities by foreign affiliates of the US firms and their reverse knowledge transfer back to the US parents. They argue that technology developed abroad by US-based firms tends to be introduced about as rapidly in the US as in the country where it is developed. As a result, US firms' competitiveness depends as much on overseas R&D as on domestic R&D. In the same vein, Kotabe (1989) has

added further evidence to support the importance of parent-affiliates' R&D activities in determining the firm's global competitiveness.

Therefore, as a result of the geographical decoupling of factors across geographic space made possible by technological modularization, two major patterns emerge from the above discussion. First of all, developed countries, where R&D in high-tech sectors has been traditionally conducted, locate innovative activities in BRICKST to further strengthen knowledge production at home in those sectors. To this end, both domestic and offshore R&D in BRICKST are inputs for knowledge production in the home investing country. Secondly, knowledge production in the home investing countries in medium- and low-tech sectors is mainly fed by R&D inputs from BRICKST economies where more standardized innovative activities have been increasingly offshore. Thus, we test the following hypotheses:

H2a: Knowledge production in high-tech sectors in the home investing country is fed by both R&D offshore in BRICKST and domestic R&D.

H2b: Knowledge production in medium- and low-tech sectors in the home investing country is fed mainly by R&D offshore in BRICKST.

Empirical analysis

The model

We frame our model within the traditional literature à la Griliches-Jaffe (see Griliches, 1979, 1990; Jaffe, 1986, 1989), where the relationship between innovative inputs and outputs is modeled through the so-called knowledge production function (KPF), a function intended to represent the transformation process leading from innovative inputs (both internal and external) to innovative outputs.¹ Specifically, it can be written as follows:

$$O_i = I_i^\lambda E_i^\varphi \quad (1)$$

Where O is the innovative output, i.e., the knowledge produced; I is the internal innovative input and E is the external innovative input; i is used to index variously countries, industries or firms; for our study, it will index OECD countries. The parameters λ and φ indicate the elasticity of new knowledge as concerns internal and external input, respectively.

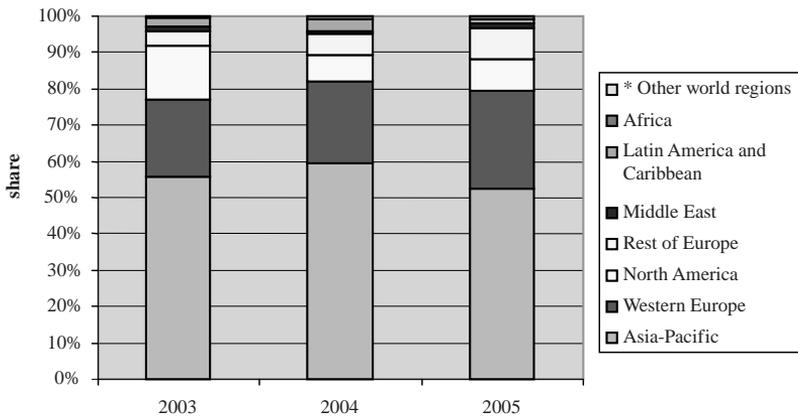


Figure 7.1. R&D offshoring (from OECD countries) by world region destinations, 2003–05.

Source: Authors' calculations on FDI Markets database.

Accordingly, our econometric model relies on the estimation of a *knowledge production function* where the production of knowledge is measured by patents (at the country level) and external and internal innovative inputs are measured by each country's R&D projects abroad and domestic R&D expenditures, respectively. Additionally, as the literature on MNEs has acknowledged, the importance of knowledge spillovers stemming from the presence of foreign actors (for a recent survey, see Castellani and Zanfei, 2006), we "augmented" KPF by controlling for the presence of foreign MNEs in each country.

Data and variables

Data on R&D projects abroad come from the database FDI Markets (previously called OCO Monitor, see www.ocoglobal.com), which records information on greenfield FDI for all sectors and home/host countries, from 2003 to the present. Specifically, we selected data on projects concerning R&D activities, as far as OECD home countries are concerned, over the three-year period 2003–05. Figure 7.1 and Table 7.1 illustrate the role of emerging countries in hosting R&D activities by OECD countries. The figures show that BRICKST countries host about half of the whole foreign R&D activity.

As far as the variables employed in our model are concerned, our dependent variables aim at proxing the production of knowledge in

Table 7.1 *R&D offshoring from OECD countries to BRICKST*

Destination country	2003	2004	2005
	<i>(Number of projects)</i>		
Brazil	4	1	2
China	49	66	71
India	33	52	53
Russia	3	4	9
Singapore	7	16	9
South Korea	7	10	7
Taiwan	13	9	3
Total BRICKST	116	158	154
Share BRICKST	48.33	53.20	49.20
Overall total	240	297	313

Source: Authors' calculations on fDI Markets database.

the home country, in the period following the R&D offshoring initiatives. Therefore, following Griliches (1979), we use the total number of patents associated to research activities carried out in OECD home countries.² The data source is the OECD Science and Technology Indicators, and specifically *PATFAM*, and is measured by the country's triadic patent families over the period 1995–2005. Triadic patent families are defined at OECD (Dernis and Khan, 2004) as a set of patents filed at the European Patent Office, the US Patent and Trademark Office and the Japan Patent Office which protect the same invention and share the same priority date. The OECD has developed triadic patent families in order to reduce the major weaknesses of the traditional patent indicators that are commonly constructed on the basis of information from a single patent office. While patents filed at a given patent office represent a rich source of data, these data show certain weaknesses. The home advantage bias is one of them, since, proportionate to their inventive activity, domestic applicants tend to file more patents in their home country than non-resident applicants. Furthermore, indicators based on a single patent office are influenced by factors other than technology, such as patenting procedures, trade flows, proximity, etc. In addition, the value distribution of patents within a single patent office is skewed: many patents are of low value and few are of extremely high value. Simple patent counts would therefore give equal weight to all patent applications.

Additionally, in order to take into account the possible impact of R&D offshoring on the sectoral composition mix,³ we also considered the following dependent variables:

- *PS_HIGH* is measured by the number of patents⁴ associated to innovative activities carried out in the OECD home countries and filed under the Patent Co-operation Treaty in the period 2002–04 in high-technology sectors.
- *PS_MHIGH*, *PS_MLOW*, and *PS_LOW* measure the number of patents associated to innovative activities carried out in the OECD home countries and filed under the Patent Co-operation Treaty in the period 2002–04 in medium-high, medium-low and low technology sectors, respectively.

In order to further test the impact of R&D offshore in BRICKST, we also adopted as a dependent variable the international competitiveness of the country in knowledge-intensive goods (i.e., *HT_EXP*), measured by the country's average high-tech export share over the period 2002–05 and drawn from the World Development Indicators database provided by the World Bank.

As far as our explanatory variables are concerned R&D offshoring was measured by the number of overseas R&D projects, in BRICKST countries, over the period 2003–05 (i.e., *R&DoffBRICKST*) as drawn from FDI Markets database. Domestic R&D expenditures were proxied by the country's R&D expenditures as a percentage of GDP 2005 (i.e., *R&D_GDP05*) based upon OECD data.

Finally, we also control for the presence of foreign MNEs in each country (i.e., inward FDI) and outward FDI, measured as follows. Based upon OECD data we drew a measure of FDI inflows as a percentage of GDP over the period 2000–05 (i.e., *IFDI_GDP00_05*) and a measure of FDI outflows as a percentage of GDP over the period 2000–05 (i.e., *OFDI_GDP00_05*).

Descriptive statistics and correlation coefficients are reported in Table 7. 2.

Results

Results of the econometric models are reported in Table 7.3. Specifically, our estimates suggest that our first hypothesis is confirmed, that is, that overseas R&D investments in BRICKST countries are complementary to the home country's innovative effort, new knowledge

Table 7.2 *Descriptive statistics and correlation coefficients*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mean	1487.18	5080.44	4913.94	1085.95	474.24	16.35	14.27	1.81	3.60	3.77
Std. dev.	3578.59	9666.91	8833.08	1890.95	827.16	8.41	41.78	0.96	2.26	4.10
Min	2.7	50.91	86.66	22.23	10.91	1.86	0	0.49	0.16	0.19
Max	14965.89	41481.82	30374.46	6789.27	3516.83	32.54	227	3.89	9.69	16.94
No. obs.	30	26	26	26	26	29	30	30	29	29
<i>Dependent variables</i>										
(1) PATFAM	1									
(2) PS_HIGH	0.98	1								
(3) PS_MHIGH	0.91	0.94	1							
(4) PS_MLOW	0.88	0.93	0.99	1						
(5) PS_LOW	0.92	0.98	0.96	0.96	1					
(6) HT_EXP	0.45	0.48	0.37	0.35	0.42	1				
<i>Explanatory variables</i>										
(7) R&Doff_BRICKST	0.84	0.89	0.75	0.74	0.88	0.46	1			
(8) R&D_GDP05	0.40	0.39	0.37	0.36	0.34	0.56	0.28	1		
<i>Controls</i>										
(9) IFDI_GDP00_05	-0.35	-0.32	-0.32	-0.31	-0.28	-0.05	-0.23	-0.07	1	
(10) OFDI_GDP00_05	-0.18	-0.14	-0.15	-0.14	-0.10	0.23	-0.09	0.32	0.57	1

Table 7.3 Results of the econometric models (dependent variables: patents and patent shares)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Explanatory variables	Dependent variables											
	PATFAM (1)		PS_HIGH (2)		PS_MHIGH (3)		PS_MLOW (4)		PS_LOW (5)		HT_EXP (6)	
R&Doff_BRICKST	63.45 *** (7.01)		177.00 *** (8.66)		128.86 *** (4.42)		27.34 *** (4.24)		15.35 *** (7.70)		0.07 * (1.85)	
R&D_GDP05	857.48 * (1.93)		1936.18 * (1.83)		2143.6 (1.42)		418.91 (1.25)		105.66 (1.02)		3.87 ** (2.23)	
IFDI_GDP00_05	-129.25 (-0.63)		-292.66 (-0.58)		-335.98 (-0.47)		-76.15 (-0.48)		-24.02 (-0.49)		-0.02 (-0.02)	
OFDI_GDP00_05	-125.53 (-1.03)		-257.24 (-0.74)		-307.90 (-0.62)		-53.78 (-0.49)		-8.59 (-0.25)		-0.08 (-0.17)	
Constant	-17.49 (-0.02)		421.83 (0.17)		995.26 (0.28)		300.36 (0.38)		138.11 (0.56)		8.76 * (2.14)	
No. obs	30		26		26		26		26		29	
R2	0.77		0.85		0.62		0.60		0.80		0.39	
Adj R2	0.73		0.81		0.55		0.52		0.76		0.28	
F	20.34 ***		27.38 ***		8.29 ***		7.40 ***		19.88 ***		3.61 **	

Notes: T statistics are reported in brackets.

***: significant at $p < .01$; **: significant at $p < .05$; *: significant at $p < .10$

creation and international competitiveness in knowledge-intensive goods, as depicted by the positive and statistically significant signs in all estimated models (R&Doff_BRICKST is significant at $p < .01$ in Models 1 to 5, and at $p < .10$ in Model 5). This result is in line with Kotabe's (1990) analysis back in the nineties of the impact of offshoring by US firms on their innovative ability. OECD firms have developed what have been called *dynamic* (Teece *et al.*, 1997) or *combinative* (Kogut and Zander, 1992) capabilities which enable them to acquire and synthesize new resources upon which to build new applications in a fast-changing environment.

H2a and H2b are also confirmed, as domestic R&D expenditures matter for the home country's knowledge creation but less so as the degree of innovativeness decreases. This is illustrated by the positive and statistically significant signs (at $p < .10$) of the variable R&D_GDP05 in Models 1 and 2 as well as by the statistically non-significant results gathered when running all the other models. The creation of new complex and tacit technologies is geographically concentrated in more advanced countries, while the creation of more mature and codified technologies is geographically dispersed in new fast-growing countries such as the BRICKST countries. This result seems also to confirm an international division of labor in knowledge production and the consequent rise of a market for technology (Arora and Gambardella, 2001).

As far as our control variable, both inward and outward FDI do not seem to be related to knowledge production as shown by the non-significant signs reported in the table. It should, however, be acknowledged that our dataset does not allow us to single out between origin and destination countries. Such a distinction may well shed some light on the role played in the story by inward and outward manufacturing investments.

Concluding discussion and future research agenda

Our findings suggest a positive impact of R&D offshore in BRICKST by OECD countries upon their knowledge production at home. However, such a knowledge production at home seems to benefit from both domestic R&D and R&D activities offshore in BRICKST as far as high-technology sectors are concerned, while in medium- and low-technology sectors it is primarily fed by innovative activity offshore

in BRICKST. Accordingly, on the policy front, these findings support the actions to motivate foreign R&D activity by MNCs with the due qualification that foreign investments should complement the domestic R&D of MNCs. In fact, we find only partial evidence of the evolution of offshoring strategies from home-base augmenting (HBA) to home-base replacing (HBR) innovation capabilities, pointed out by recent studies on innovation offshoring (Lewin *et al.*, 2009). However, caution should be used when attempting to draw policy implications from the study since the choice of measuring knowledge output through patents may affect our results. Not all innovations are patented and not all of them are patentable (Cohen and Levin, 1989; Griliches, 1990; Trajtenberg, 1990). In this direction, cross-industry discrimination may be revealing. Along these lines, it should be acknowledged that different innovation outputs can be seen as the outcomes of several innovation inputs and not only as the consequence of R&D investments (see Conte and Vivarelli [2005], for an empirical analysis on the Italian case). For instance, the literature suggests that more complex product innovation generally relies on formal R&D, while process innovation (where it is not easy to single out pure innovation, diffusion, and imitation with any precision) is much more related to the acquisition of external technology, both through the “embodied technical change” acquired by investment in new machinery and equipment, and through the purchasing of external technology incorporated in licences, consultancies, know-how (Freeman, 1982; Freeman *et al.*, 1982; Freeman and Soete, 1987).

Linked to the above, the study has many limitations and, therefore, our future research agenda is quite rich. First of all, as in Kotabe (1990), it is cross-sectional and the results are then based on relationships observed across various countries. Although the innovation lag period was considered, a cross-sectional study may not capture all the implications of a dynamic system which could change over time. Therefore, longitudinal studies and firm-level studies are strongly desirable to better cast the relationship between R&D offshoring and innovative activities at home before a proper conceptual logic can be developed. Firm level analyses, in particular, would allow researchers to test whether indeed smaller and medium-sized companies, which are more likely to be active in medium- and low-tech sectors, do actually adopt innovation offshoring strategies that augment their limited innovation capabilities, while larger MNEs have recently

started to replace their domestic innovative activities with R&D laboratories offshore abroad in emerging countries. Additionally, the study of complementarity vs. substitutability between innovative activities conducted abroad and those maintained at home could be empirically deepened, by using more sophisticated econometrics and non-parametric techniques. A further limitation of our study which needs to be addressed in future research refers to the R&D offshoring measure which unfortunately prevents us from controlling for the type of R&D project, i.e., whether it focuses more on *research* and/or *development*. This additional information would clearly allow a more fine-grained analysis on the dynamics of reverse knowledge flows by controlling for the characteristics of the knowledge offshore. Finally, data availability constrained our analysis to the extent that it fails to account for the technological development of the industry level for the host country firms as an important determinant in knowledge flows to home. Future research clearly needs to include this and other more micro, firm level variables which are recognized to be critical for the understanding of the offshoring phenomenon.

Notes

- 1 The KPF literature is quite broad. For a similar application on the impact of global engagement on the innovation activities of firms, see Criscuolo *et al.*, 2005.
- 2 The pros and cons of using patents as an indicator of technological activity are well known and already widely discussed in the literature (e.g., Schmookler, 1950, 1966; Pavitt, 1985, 1988).
- 3 For the classification employed see Hatzichronoglou, 1997.
- 4 Patents counts are based on the priority date, the inventor's country of residence, and fractional counts.

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