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

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Abstract -.

This paper aims to investigate whether offshoring of R&D activity in fast-growing economies impacts on the knowledge creation of home investing countries. In particular, it develops an exploratory cross-country analysis focusing on OECD countries investing in BRICKST (Brazil, Russia, India, China, Korea, Singapore and Taiwan). Specifically, by using a *knowledge production function* framework, we test whether R&D offshore in BRICKST impacts on knowledge production at home, and (if so) how it affects the sectoral focus/mix of knowledge production. Our findings suggest a positive impact of R&D offshore in BRICKST on the knowledge production of home OECD investing countries. However, 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, while in medium- and low-technology sectors it is primarily fed by innovative activity offshore in BRICKST.

Keywords: R&D offshoring, internationalization of R&D, knowledge production

1. Introduction

This paper 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 country's knowledge production (Kotabe, 1990; Hemphill, 2005), or instead they hasten a possible hollowing out and/or a polarization of home country's competences (Teece, 1987; Liberman, 2004; Bardhan and Jaffee, 2005). Despite further research conducted on this issue (e.g. Feenstra and Hanson, 1999; Egger *et al.*, 2001; Falk and Wolfmayr, 2005; Hansson, 2005; Hsieh and Woo, 2005; Gersbach and Schumtzler, 2006; Naghavi and Ottaviano, 2008), consensus on the net impact of offshoring on 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 less extent, Brazil are increasingly attracting R&D by multinationals. In particular, UNCTAD estimates (relying on the Ocomonitor database) that of the 1773 FDI projects involving R&D as a key business function during 2002-2004, no fewer than 1095 went to Eastern Europe and Asia, with India and China the most important destination countries. 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-10 of R&D investment locations behind the US and the UK. However, it has been recognized that international business (IB) research has paid limited attention to the offshoring phenomenon and that such a phenomenon poses challenges to strategic management research in understanding the development and deployment of firm-level capabilities (Doh, 2005). In addition, Doh and Pearce (2003) contend that theories of internationalization (e.g. Vernon, 1966; Johanson and Vahlne, 1990) and FDI (e.g. Dunning, 1977) have failed to adequately incorporate the distinctive nature of services and intangible activities.

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 impacts on knowledge production at home, and (if so) how it affects the sectoral focus/mix of knowledge production. 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. However, 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, while in medium- and low-technology sectors it is primarily fed by innovative activity offshore in BRICKST.

2. Theoretical framework and hypotheses

Despite of 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 paper, we will use the term “offshoring” in general although focusing on captive offshoring only. Along the lines of recent studies (Venkatraman, 2004; Bunyaratavej *et al*., 2007), we then defined international offshoring as the practice of placing activities at offshore locations outside the investing home country. Our definition does not necessary 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 re-location of activities in other countries may well co-exists with the persistence of the same type of activities at home. We, therefore, use the terms offshoring as interchangeable with internationalization.

Our definition intends to capture the fact that offshoring *per se* has been a long-lasting phenomenon in the IB scenario and is far to represent something new. The localization of manufacturing work and blue-collar jobs is a strategy adopted long time ago. Thanks to the fast pace of technological developments, companies have been able to increasingly created value by globally dispersing individual activities where they can be most efficiently executed (Zaheer and Manrakhan, 2001; Zaheer and Zaheer, 2001). However, what is new about the phenomenon at hand is the increasingly location abroad of a series of white-collar business processes that only until few decades ago could be executed only at home (Dossani and Kenney, 2006). The activities internationally offshore have over time climbed back 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 rising many concerns is the increased offshoring of innovative activity in fast-growing emerging countries such as BRICKST. 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 is associated with 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 (Kuemmerle, 1999; Ambos, 2005; Cantwell and Mudambi, 2005). 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 countries of developing Asia (Lewin and Couto, 2006), which have emerged as new technology producers (Athreye and Cantwell, 2005), and in particular in BRICKST. However, this 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 and between subsidiaries (Håkanson and Nobel, 2001). Theory and evidence on MNEs (Cantwell, 1995; Almeida, 1996; 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. According to this "technology-seeking" or "knowledge-seeking" argument, firms may expand abroad in search of capabilities complementary to those available in their home markets (Cantwell 1989). This suggests that firms use knowledge-seeking investments also to source technical diversity (Chung and Alcacer, 2002). Accordingly, 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 (Bunyaratevej *et al*., 2007). This emphasis on intellectual capital seems to suggest that offshoring decisions are increasingly asset-seeking due to the immobility of knowledge. Moreover, being knowledge partially tacit, its transfer requires frequent interaction (Kogut and Zander, 1992). *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 fed knowledge production. In line with the knowledge-seeking argument, we then contend that

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

The knowledge-seeking literature does recognize the significance of home country knowledge production, which provides the necessary absorptive capacity to source new complementary knowledge abroad (Cantwell, 1989). *De facto*, research on the globalization of innovation has shown that technological activities are concentrated in the home country and foreign R&D shares greatly vary amongst sectors across countries (Patel and Pavitt, 1991). Along these lines, 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. Accordingly, Hirshfeld and Schmidt (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, at least in the foreseeable future (Lewin et al., 2008; Manning et al., 2008). Therefore, developed countries, where R&D in high-tech sectors has been traditionally conducted, offshore 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. Thus, we then contend that

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 .

Sectoral difference in the geography of knowledge production have been explain 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 innovative activities closer to market, and sectors where knowledge production is more routinised and standardized more easily offshore (Mudambi, 2008). Although offshoring is no longer limited to standardized IT or business processes, but increasingly involves new product development activities, R&D and product design (Maskell *et al.*, 2006; Engardio and Einhorn, 2005; Subramaniam and Venkatraman, 2001; Patel and Vega 1999), R&D inputs from BRICKST economies primarily affect knowledge production in the home investing countries in medium- and low-tech sectors.

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

3. The empirical analysis

3.1. The model

We frame our model within the traditional literature à la Griliches-Jaffe (see Griliches, 1979; Jaffe, 1986, 1989). These works highlight, through the modelling of various specifications of the knowledge production function, as spillovers from private research have a narrower range than whose stemming from public research, even if they both often cross administrative boundaries (Anselin et al., 1997; Autant-Bernard, 2001).

However, the link between scientific research, technological innovation and economic growth was already demonstrated empirically by Mansfield (1972), Rosenberg (1974), Sveikauskas (1981), and Adams (1990).

The econometric model relies on the estimation of an *augmented knowledge production function* (Griliches, 1979), where the knowledge production of the OECD countries in the sample is modelled as a function of the country's R&D projects abroad and domestic R&D expenditures. Additionally, as the literature on MNEs has acknowledged the importance of spillovers stemming from the presence of foreign actors in a geographical area (for a recent survey, see Castellani and Zanfei, 2006), we also control for the presence of foreign MNEs in each country.

3.2. Data and variables

Data on R&D projects abroad come from the database fDI Markets (previously called OCO Monitor, see http://www.ocoglobal.com), which records information on greenfield FDI for all sectors and home/host countries, starting in 2003 up to now. Specifically, we selected data on projects concerning R&D activities, as far as OECD home countries are concerned, over the three year period 2003-2005. Figure 1 and Table 1 illustrate the role of emerging countries in hosting R&D activities by OECD countries. Specifically, it emerges that BRICKST countries host about half of the whole foreign R&D activity.

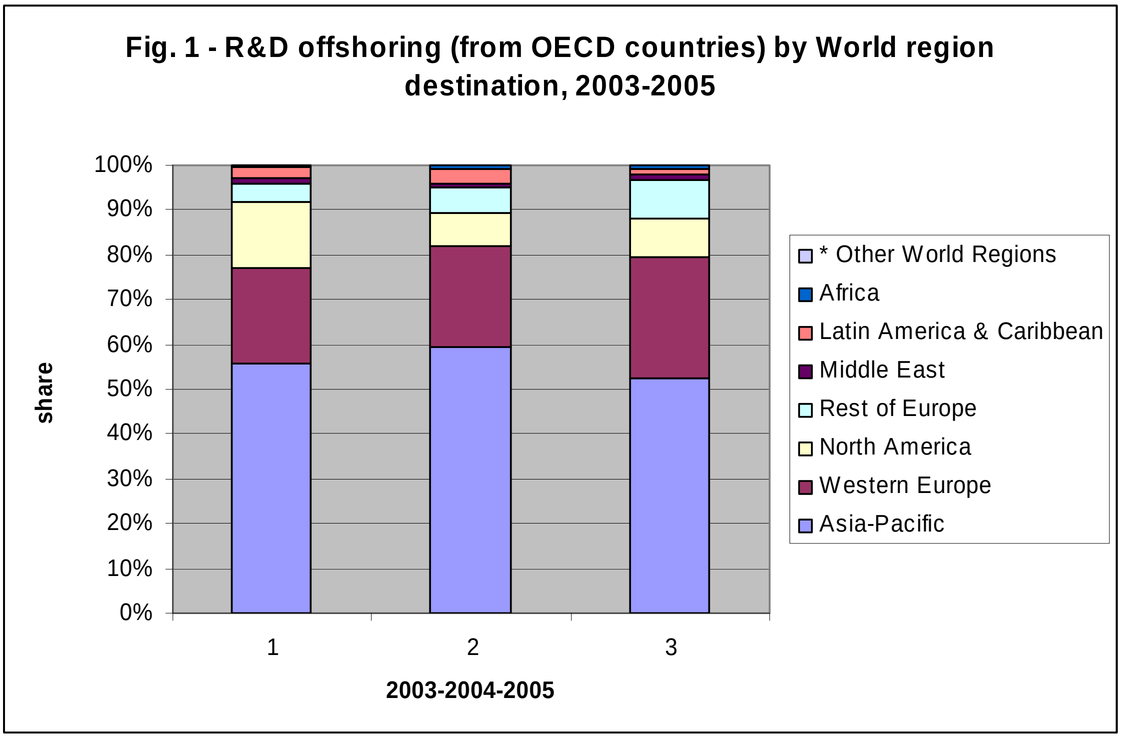

Table 1 – OECD countries' R&D offshoring to BRICKST countries

Destination Country	2003	2004	2005
Brazil	4	1	2
China	49	66	71
India	33	52	53
Russia	3	4	9
Singapore	7	16	9
S. 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**

As far as the variables employed in our model, our dependent variables aim at proxying the production of knowledge in the home country, in the period following the R&D offshoring initiatives.Therefore, according to Griliches and Jaffe, we use the total number of patents associated to research activities carried out in OECD countries. Namely:

- PATFAM is measured by the country’s triadic patent families[i] over the period 1995-2005 (the source is the OECD Science and Technology Indicators).

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

- PS_HIGH is measured by the number of patents[1] in PCT filings[2] in the period 2002-04 in high technology sectors (see Hatzichronoglou, 1997). The source of data is the OECD Science and Technology Indicators 2007.
- Likewise, PS_MHIGH, PS_MLOW, and PS_LOW concern medium-high, medium-low and low technology sectors.

Finally, we also adopted as a dependent variable, the international competitiveness of the country in knowledge-intensive goods, HT_EXP, measured by the country’s average high-tech export share over the period 2002-2005 (the source of data is the World Development Indicators database, World Bank).

As far as our explanatory variables:

- R&Doff_BRICKST: No. of overseas projects over the period 2003-2005 in BRICKST countries, (Source: OCO Monitor);

Internal R&D expenditures are proxied by R&D_GDP05 (R&D expenditures as a percentage of GDP 2005, Source: OECD).

[1] Patents counts are based on the priority date, the inventor's country of residence and fractional counts.
[2] Patent applications filed under the Patent Co-operation Treaty, at international phase, designating the European Patent Office.

Finally, we also control for inward and outward FDI, measured as such:

- IFDI_GDP00_05: FDI inflows as a percentage of GDP over the period 2000-2005 (Source: OECD);
- OFDI__GDP00_05: FDI outflows as a percentage of GDP over the peirod 2000-2005 (Source: OECD).

Descriptive statistics and correlation coefficients are reported in Table 2.

4. Results and conclusions

Results of the econometric models are reported in Table 3. Specifically, our estimates suggest that:

- Our first hypothesis is confirmed, that is overseas R&D investments in BRICKST countries are complementary to home country's innovative effort , new knowledge 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 1-5, and at $p<.10$ in model 5). This result is in line with Kotabe (1990) analysis back in the nineties of the impact of offshoring by US firms on their innovative ability**.** In that, 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.
- Our second hypothesis is also confirmed, as domestic R&D expenditures matter for 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 the first and second column 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 plaid in the story by inward and outward manufacturing investments

On the policy front, these findings support the actions to motivate foreign R&D activity of MNCs; however, suggestions with respect to encouraging FDI in R&D following such findings must take into account that this foreign investment 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., 2008).

Table 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
Dependent variables										
(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				
Explanatory variables										
(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		
(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 3 – Results of the econometric models (dependent variables: patents and patent shares)

	Dependent variables											
Explanatory variables	PATFAM		PS_HIGH		PS_MHIGH		PS_MLOW		PS_LOW		HT_EXP	
	(1)		(2)		(3)		(4)		(5)		(6)	
R&Doff_BRICKST	63.45	***	177.00	***	128.86	***	27.34	***	15.35	***	0.07	*
	(7.01)		(8.66)		(4.42)		(4.24)		(7.70)		(1.85)	
R&D_GDP05	857.48	*	1936.18	*	2143.6		418.91		105.66		3.87	**
	(1.93)		(1.83)		(1.42)		(1.25)		(1.02)		(2.23)	
IFDI_GDP00_05	-129.25		-292.66		-335.98		-76.15		-24.02		-0.02	
	(-0.63)		(-0.58)		(-0.47)		(-0.48)		(-0.49)		(-0.02)	
OFDI_GDP00_05	-125.53		-257.24		-307.90		-53.78		-8.59		-0.08	
	(-1.03)		(-0.74)		(-0.62)		(-0.49)		(-0.25)		(-0.17)	
Constant	-17.49		421.83		995.26		300.36		138.11		8.76	**
	(-0.02)		(0.17)		(0.28)		(0.38)		(0.56)		(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	**

Note: T statistics are reported in brackets

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

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Patent families 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.

The OECD has developed *triadic patent families* in order to reduce the major weaknesses of the traditional patent indicators described above. Triadic patent families are defined at the OECD as a set of patents taken at the European Patent Office (EPO), the Japan Patent Office (JPO) and US Patent and Trademark Office (USPTO) that protect a same invention. In terms of statistical analysis, they improve the international comparability of patent-based indicators, as only patents applied for in the same set of countries are included in the family: home advantage and influence of geographical location are therefore eliminated. Second, patents included in the family are typically of higher value: patentees only take on the additional costs and delays of extending protection to other countries if they deem it worthwhile.

The criteria for counting triadic patent families are the earliest priority date (first application of the patent world wide), the inventor's country of residence, and fractional counts. Owing to time lag between the priority date and the availability of information, 1998 is the latest year for which triadic patent families data is almost completely available. Data from 1998 onwards are OECD estimates based on more recent patent series (*nowcasting*).

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[i] Triadic patent families are defined at OECD (Denis and Khan, 2004) as a set of patents filed at the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO) which protect the same invention.