R&D offshoring and its effects on the innovation performance of Chinese firms

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Abstract

Involvement in R&D offshoring can result in loss in the ability of the offshoring firms to innovate. To prevent this, firms can design strategies to foster technology transfer by enhancing possibilities to re-adapt and re-invent the foreign-developed technologies. This paper examines the effect of two different modes of governance of R&D offshoring –market and hierarchies - on the innovation activity of indigenous firms, as well as how strategies for enhancing re-adaptation, innovation around and re-invention moderates those effects. We examine this issue empirically using data from 2011 to 2014 for a sample of 312 firms, classified as 'high and new-tech enterprises' located in the Hebei Province of China. Results suggest that governing R&D offshoring through market influence positively firms' innovation activity, while vertically integrating R&D offshoring though the establishment of R&D labs in industrialized countries has a negative effect on firms' innovation. Collaboration with domestic universities and public research organizations seem to support reinvention of foreign-developed technologies, accessed either through market or hierarchies, and in this way it enhances the effect of R&D offshoring on firms' innovation activity. On the contrary, employment of foreign staff moderates negatively the effect of R&D offshoring, especially of the vertical integration mode, suggesting that foreign staff may foster knowledge transfer and adaptation but not necessarily re-invention or innovation around the foreign-developed technologies. Our study extends the debate of R&D offshoring to domestic independent firms and suggests boundary conditions for reaping benefits from R&D offshoring.

1. Introduction

Increasingly the value-creating R&D activities are delocalized to different locations for both market and technology reasons. The literature has elaborated frameworks to explain which drive different types of R&D delocalization (Nieto & Rodríguez, 2011; Von Zedtwitz & Gassmann, 2002; Belderbos et al., 2015) and it has provided evidence on how these R&D relocation activities may increase the performance of firms and their regions (Castellani & Pieri, 2013; Rodríguez & Nieto, 2015; Nieto & Rodríguez, 2011). Benefits from R&D offshoring are mostly explained by the ability of firms to foster and benefit from reverse technology transfer (Criscuolo et al., 2005; Criscuolo, 2009). There is however little evidence on how different strategies for adaptation and re-invention of the foreign-developed technologies influence the innovative ability of R&D offshoring firms. In addition, little is known about the effect of R&D strategies of emerging economy firms, with the R&D offshoring literature focusing almost exclusively on Western multinationals and their affiliates.

Hence, the objective of this study is twofold. First, it aims at examining the effect of R&D offshoring for domestic firms. The governance mode of technology-development offshoring may influence the ability to keep up with the pace of technological development (Castellani & Pieri, 2013; Rodríguez & Nieto, 2015; Nieto & Rodríguez, 2011), we distinguish two governance modes of R&D offshoring; through the market (i.e. R&D outsourcing to foreign suppliers), and through hierarchies (i.e. creation of R&D labs abroad). Second, this study aims at examining how indigenous firms' strategies to adapt or to re-invent foreign-developed technologies moderate the effect of R&D offshoring on innovative activity.

Empirically, we examine this issue using data from 2011 to 2014 for a sample of 312 firms, classified as 'high and new-tech enterprises' located in the Hebei Province of China. Results suggest that governing R&D offshoring through market influence positively firms' innovation activity, while ~~vertically integration~~ of R&D offshoring has a negative effect on firms' innovation. Collaboration with domestic universities moderates positively the effect of both modes of R&D offshoring, suggesting that it permits firms to reinvent foreign-developed technologies. On the contrary, employment of foreign staff moderates negatively the effect of

both modes of R&D offshoring, especially of vertical integration mode, suggesting that foreign staff may enhance adaptation but not innovation around the foreign-developed technologies. Hence, our study extends the debate of R&D offshoring to domestic independent firms and suggests boundary conditions for reaping benefits from R&D offshoring.

This paper is organized as follows. The paper is organized as follows. Section 2 discusses the effect of R&D offshoring on innovation activity of offshoring firms, as well as the moderating effect of strategies to adapt and reinvent foreign-developed technologies. Section 3 presents the data and discusses the method of analysis. The results are reported in Section 4. Section 5 concludes the paper.

2. R&D offshoring and innovative activity of offshoring firms

R&D activities have become increasingly delocalized to different locations for both market and technology reasons (Cantwell, 1995; Von Zedtwitz & Gassmann, 2002; Belderbos et al., 2015). While globalization of R&D activities affects domestic and multinational firms as well as developed and emerging regions, the studies on the effects of R&D relocation activities on the performance of firms and their regions tend to focus on multinational firms and on developed country regions (Castellani & Pieri, 2013; Rodríguez & Nieto, 2015; Nieto & Rodríguez, 2011).

In an emerging economy, indigenous firms' decision to import technology reflects' firms efforts to access technology which most likely could not develop internally or access in the domestic market. Investment in R&D labs abroad may reflect indigenous firms' efforts to get preferential access to advanced technological infrastructure, to skilled labour force, and strategic complementary assets to develop new technologies (Cantwell & Mudambi, 2005; Manning et al., 2008), or to adapt their products to local tastes and regulation (Castellani & Pieri, 2013; Von Zedtwitz & Gassmann, 2002).

However, the effect of R&D offshoring on the innovation activity of offshoring firms may depend on their ability to engage in creative adaptation and/or in re-inventing the foreign-developed technologies (Lall, 1992; Kim, 1998; Castellani & Pieri, 2013).

This risk of domestic firms to lose or not being able to build innovative capabilities, and to lose the path with technology development may be somehow more relevant when firms invest in R&D labs abroad than when they rely on global market to access technology. When acquiring foreign technology from the market, the firm's managers understand that the technology is not owned by the firm. Hence, managers are fully conscious that to be able to upgrade in the value chain and get higher returns, it is crucial that the firm they manage develops internal competences to produce the technology. Therefore, they may put efforts in planning and in investing in a series of sequential and parallel capability building strategies (including preferential contracts with technology suppliers) so that the firm could be able to engage in more value creating activities associated with technological development (Lall, 1992; Kim, 1998). Instead, when firms invest in R&D labs abroad, managers may be more likely to believe that they own the technology, once the technology was developed by their R&D labs abroad. In this case, without feeling the need to keep the pace with technological development and to build internal innovative capabilities, managers may neglect and/or underinvest in learning from the foreign-developed technologies. Hence, we expect that:

H1: Investment in imported technologies may have a positive effect on the innovative activity of offshoring firms

H2: Investment in R&D labs abroad may have a negative effect on the innovative activity of offshoring firms

3. Investment in adapting and re-inventing foreign-developed technologies

To enhance firms' technological and innovative capabilities, the firm may invest in a series of activities to create new knowledge by using foreign-developed technologies (Kim, 1998). Along with favorable institutional set up, attracting foreign staff and engaging with local public research organizations have been identified as the main mechanisms that have

permitted indigenous firms to build capabilities to reverse engineer and innovate around foreign technologies and in this way achieve technological catching up (Lall, 1992; Mazzoleni & Nelson, 2007). Next, we will discuss how firms' strategies to attract foreign staff and to collaborate with domestic public research organizations could moderate the effect of R&D offshoring on their innovative performance.

3.1. Foreign staff and the effect of R&D offshoring on innovative activity of offshoring firms

By sharing the language and the cultural set up with foreign engineers, and by being immersed in the reality of the technology buyer, foreign resident staff may more accurately communicate the technological and organizational conditions of using the foreign technology. This frame of mind and technological competences of foreign staff may help indigenous firms to identify the customized technological solutions that the firm needs and report them to the foreign developers (Zheng et al., 2011). Foreign staff may also have the competences to facilitate adaptation in locus of the foreign-developed technologies. Hence, Employment of a large share of foreign residents has been found to reflect firms' efforts to integrate global technological networks, as well as to access tacit knowledge on how to use the technology (Mazzoleni & Nelson, 2007).

Foreign staff may however ignore the market and institutional set up of the indigenous firm, and their mind frame may be too close to that of the foreign engineers involved in developing the technology. Hence, employment of a large share of foreign staff may facilitate the use of the foreign-developed technology, but it may less efficient to encourage or support indigenous firms to develop competences to use it creatively to innovate. Hence we expect that:

H3: The share of foreign staff moderates negatively the effect of R&D offshoring on firms' innovative activity

3.2. Domestic public research organizations and the effect of R&D offshoring on innovative activity of offshoring firms

Collaboration with domestic universities and institutes is a form by which firms can get access to resources and support to overcome technological problems in the process of adopting foreign-developed technologies to their production. Local universities and institutes seem able to support organizational and management changes required to accommodate technological developments (Bodas Freitas et al., 2014). They also have access to foreign knowledge and linkages that permit better evaluation of the available technology to acquire and develop (Mazzoleni & Nelson, 2007).

In addition, collaboration with domestic universities and technological institutes may support indigenous firms in the process of reverse engineering the technology or in the process of development of new technological applications based on the foreign technologies (Giuliani & Arza, 2009; Bodas Freitas et al., 2013). Not only they may have competences in basic R&D that may permit to solve technological problems, but they also have their own network of domestic and international linkages that provides them with information on the most deeming demanded technological development around the existing technology (Mazzoleni & Nelson, 2007).

Thus, collaboration with domestic universities and technological institutes may enhance the ability of firms to reinvent and to innovate around the foreign-developed technology. Hence, we expect that:

H4: Collaboration with domestic public research organizations moderates positively the effect of R&D offshoring on firms' innovative activity

4. Data and Methods

4.1. Data

Our analysis focuses on firms located in the Hebei province of China and classified as HNTE. Hebei is an important region bordering five provinces and including two municipalities—Beijing (the capital of China) and Tianjin (the famous trading port in north China). The tight

connection between Hebei and the important Tianjin trading port has favoured the development of export activity in Hebei.

We use an original survey dataset that contributes to the "Statistical report for enterprises in National high- and new-tech industrial development zone (in Hebei Province)". This survey was conducted by the MSTC and is compulsory for all industrial enterprises classified as HNTE by MSTC. Thus, this survey provides complete coverage of HNTEs in Hebei province. According to the latest regulation, effective from 2008, to qualify as a HNTE an enterprise must meet the required personnel structure (with at least 30% of employees college graduates and at least 10% of employees engaged in R&D work) and R&D expenditure (with at least 3%-6% [1] of total revenue invested in R&D and 60% of R&D expenditure incurred in China), be registered in mainland China for at least one year, and own the proprietary intellectual property rights to the technology used for production of its main goods or services. [2]

The survey was conducted in 2011, 2012, 2013, 2014 and the data collected reflect the situation in the previous year. The survey covered 658 firms located in Hebei province. After excluding firms with missing information on some variables or operating in the agriculture and service sectors, we were left with a total of 312 manufacturing firms that answered the survey in all the four years. These firms operate in 25 industries, ranging from Food manufacturing and Textile manufacturing to Measuring instruments and machinery.

In terms of ownership, the investigated firms fall into five types –the majority are domestically owned *private firms* (63%), while the next biggest category is *state-owned firms* (17%), followed by *collective firms* (7%), *Hong Kong-Taiwan-Macao firms* (3%), and *foreign-owned firms* (5%).[3]

[1] It will be 6% if the revenue is below RMB50 million, 4% if revenue is between RMB50 million and 200 million, and 3% if revenue is above RMB200 million.

[2] The HNTE's products or services must furthermore fall into one of the state-supported sectors (i.e. Electronic information technology; Biological and medical technology; Aviation and space technology; New materials technology; High-tech services; New energy and energy conservation technology; Resources and environmental technology; Transformation of traditional sectors through new technologies) (for more details, see Cao, 2008; Stender and Wang, 2008 that used earlier waves of this survey).

[3] Results do not change if we exclude foreign-owned firms from the sample.

4.2. Variables

4.2.1. Dependent variable

We measure innovation by the total number of patent applications in any patent office. While patent is one of a variety of mechanisms, from secrecy to lead time to complex designs, that firms use to protect their technological innovations (Hall, Helmers, Rogers, & Sena, 2014), and in spite of its limitations as a proxy for innovation - being costly and not assuring protection against imitation-, especially in emerging countries, use of patents have several advantages (Cohen et al., 2000). Patents application is an objective measure of innovation outcomes in firms. Even in emerging economies, patenting may be considered a prudent financial decision as when a firm patents it expects the patented innovations to have a reasonable market return or relevance from advancing certain technologies.

4.2.2. Independent variables

To measure the two forms of governing R&D offshoring we use two variables. *ImpTech* is a dummy variable that take the value 1 when a firm registers a positive value for the total expenses in acquisition of foreign technology and 0 otherwise. This variable captures the extension of firms' engagement in using the market to access foreign-developed technology. *ForRDlabs* has the value 1 when a firm has an R&D lab in the US, Japan or Europe. This variable provides information on the extension of firms' involvement in R&D offshoring through hierarchical governance mode.

To measure the degree of firms' investment in the adaptation of foreign-developed technologies we use two moderating variables: the variable *ForStaff* takes the value 1 if a company has foreign employees that lived in China for at least six consecutive months, while *DomColl* has a value of 1 if a firm spends in collaboration with domestic colleges, universities or technological institutes.

4.2.3. Control Variables

Once large firms have more resources and are more likely to innovate, we control for firm size, by including in the regression the logarithm of the number of employees (*Size*). Firms that are part of a group may have more resources to innovate, but also may use different channels for accessing foreign technologies. Hence we include the dichotomous variable group that provides information on whether or not the firm is part of a group (*Group*). We also included dichotomous variable capturing information on whether or not is foreign-owned.

As firms that spend more on R&D activities are more likely to innovate, we include in the regression firms' expenditures in R&D as a share of sales revenue (*R&D*) and the share of government-funded research in R&D (*Govtfund*). We also control for the share of employees with master's degree (*Edum*).

As firms exposed to international markets may be more likely to innovate, we include a dichotomous variable that provides information on whether or not the firm exports (*Export*). In addition, we control for firms' age by including the log of the number of years that the firm existed since foundation (*Age*).We also control for firms' ownership with the variable *ForFirm* that takes the value 1 if the firm has non-Chinese ownership. We adopt a fixed effect model that allows us to account for unobserved heterogeneities among firms including differences in sectors and markets in which firms operate that may affect the degree of innovation opportunities.

Table 1 provides a summary of the statistics for all the variables, as well as the correlation coefficients among them.

Table 1. Summary statistics and Correlation Matrix

No	Variables	MEAN	SD	MIN	MAX	Correlation Matrix									
1	Patents	1.77	4.82	0.00	106.00	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
2	ImpTech	0.02	0.14	0.00	1.00										
3	ForRDlab	0.01	0.10	0.00	1.00	0.04									
4	DomColl	0.28	0.45	0.00	1.00	0.07	0.08								
5	ForStaff	0.08	0.27	0.00	1.00	0.14	0.23	0.08							
6	RD	0.18	1.97	0.00	57.56	-0.01	-0.01	-0.03	-0.01						
7	Govtfund	0.06	0.29	0.00	8.32	-0.01	0.01	0.06	0.00	0.00					
8	Export	0.49	0.50	0.00	1.00	0.07	0.09	0.09	0.18	-0.06	-0.04				
9	Size	5.62	1.23	0.69	10.66	0.12	0.09	0.29	0.26	-0.06	-0.11	0.34			
10	Edu	0.00	0.00	0.00	0.04	-0.01	-0.02	-0.08	-0.07	0.17	0.05	-0.13	-0.31		
11	ForFirm	0.07	0.26	0.00	1.00	0.11	0.03	0.04	0.20	-0.02	-0.03	0.11	0.21	-0.05	
12	Age	2.31	0.54	0.00	4.08	0.02	0.03	0.07	0.00	-0.03	-0.02	0.06	0.20	-0.06	0.03

4.3. Data analysis

As our dependent variable is a count variable, we used a Poisson model to examine the relationship between R&D offshoring and innovation activity of the firms, as well as the moderating effect of firms' investment in adaptation and reinvention of the foreign-developed technologies. The model was estimated with robust standard errors which tend to correct also for over dispersion of the dependent variable. We used year dummies to control for fluctuations that may affect temporal variations in the behavior of all firms.

5. Results

Table 2 provides the estimation of the innovation activity of the firm. The coefficient of investment in imported technology is positive and significant, while the coefficient of investment in R&D labs abroad is negative and significant. These results provide support for H1 that stated that Investment in imported technologies may have a positive effect on the innovative activity of firms and for H2 that stated that Investment in R&D labs abroad may have a negative effect on the innovative activity of firms.

Results also show that the coefficient of investment in collaboration with domestic public research organization and the coefficient of the presence of foreign staff on total employment re not significant, suggesting that there is no significant direct effect on the innovation activity of the firm. Instead these variables moderate significantly the effect of R&D offshoring on innovation.

The coefficient of the interaction between foreign staff presence and investment in imported technologies is negative and significant. The coefficient of the interaction between foreign staff and investment in R&D labs abroad, although negative in two of the three specifications, is not significant. These results provide partial support to H3 that stated that the share of foreign staff moderates negatively the effect of R&D offshoring on firms' innovative activity.

The coefficient of the interaction between investment in collaboration with domestic PROs and imported technologies is significant and positive. Similarly, the coefficient of the

interaction between investment in collaboration with local PROs and R&D labs abroad is significant and positive in all but the baseline model (model 5). These results support H4 that proposed that investment in collaboration with local PROs moderate positively the effect of R&D offshoring on firms' innovative activity.

Table 2. Fixed effects Poisson estimates of drivers of patented innovations

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ImpTech	0.5869**	-0.5111*	0.7594**	-0.3842				-0.3863
	(0.2942)	(0.3092)	(0.3346)	(0.3125)				(0.3146)
ForRDlab	-0.7588*	-0.8887*	-0.6873*	-0.7681**	-2.3398*	-0.8940	-1.5216	-1.4438
	(0.4391)	(0.4784)	(0.3709)	(0.3642)	(1.3454)	(0.9824)	(1.6098)	(1.5766)
DomColl	0.0183	-0.0529	0.0218	-0.0565	-0.0079	0.0089	-0.0099	-0.0746
	(0.1111)	(0.0987)	(0.1137)	(0.0991)	(0.1074)	(0.1072)	(0.1074)	(0.0993)
ForStaff	-0.1655	0.0488	-0.0907	0.1704	-0.3740	-0.3713	-0.3731	0.1665
	(0.1911)	(0.1605)	(0.1870)	(0.1620)	(0.3245)	(0.3262)	(0.3248)	(0.1623)
ImpTech x ForStaff			-1.0257*	-1.4302***				-1.4464***
			(0.5319)	(0.5091)				(0.5160)
ForRDlab x ForStaff						0.2820	-1.2715	-1.4307
						(1.0787)	(1.5552)	(1.5315)
ImpTech x DomColl		1.7195***		1.9098***				1.9047***
		(0.4563)		(0.4258)				(0.4278)
ForRDlab x DomColl					1.9206		2.3335**	2.2534*
					(1.4592)		(1.1797)	(1.1748)
RD	-0.0257**	-0.0286**	-0.0260**	-0.0294***	-0.0249**	-0.0247**	-0.0249**	-0.0297***
	(0.0115)	(0.0111)	(0.0115)	(0.0111)	(0.0117)	(0.0117)	(0.0117)	(0.0111)
Govtfund	-0.0082	-0.0136	-0.0096	-0.0152	-0.0030	-0.0056	-0.0024	-0.0121
	(0.1076)	(0.1054)	(0.1076)	(0.1055)	(0.1069)	(0.1069)	(0.1070)	(0.1056)
Export	0.2490	0.2602	0.2407	0.2461	0.2711	0.2703	0.2702	0.2448
	(0.1830)	(0.1839)	(0.1816)	(0.1827)	(0.1851)	(0.1858)	(0.1854)	(0.1820)
Size	0.5165***	0.4697***	0.5016***	0.4439***	0.5684***	0.5757***	0.5681***	0.4374***
	(0.1553)	(0.1402)	(0.1505)	(0.1348)	(0.1944)	(0.1942)	(0.1945)	(0.1357)
Edu	26.2068	24.3683	25.6502	23.5284	27.7005	27.8894	27.6663	23.3212
	(18.0757)	(17.6451)	(17.9677)	(17.5215)	(18.6861)	(18.7563)	(18.6848)	(17.4615)
ForFirm	1.2246***	1.2463***	1.2217***	1.2453***	1.2281***	1.2267***	1.2272***	1.2456***
	(0.2256)	(0.2289)	(0.2256)	(0.2293)	(0.2224)	(0.2230)	(0.2223)	(0.2285)
Age	-0.2546	-0.1935	-0.2669	-0.1925	-0.2844	-0.2897	-0.2838	-0.1873
	(0.2293)	(0.2233)	(0.2289)	(0.2226)	(0.2381)	(0.2379)	(0.2382)	(0.2232)
Group	-0.0731	-0.1590	-0.1070	-0.2188	-0.0278	-0.0315	-0.0284	-0.2154
	(0.1985)	(0.2081)	(0.2006)	(0.2105)	(0.2083)	(0.2089)	(0.2084)	(0.2102)
Year dummy	included	included	included	included	included	included	included	included
Observations	1,235	1,235	1,235	1,235	1,235	1,235	1,235	1,235
Number of firms	312	312	312	312	312	312	312	312
Log-Psuedolikelihood	-1204	-1191	-1201	-1185	-1210	-1213	-1210	-1182

6. Conclusions

This paper set out to examine the effect of two different modes of governing R&D offshoring –market and hierarchy - on the innovation activity of offshoring firms in an emerging economy, as well as the moderating role of strategies to foster re-adaptation, innovation-around and re-invention of foreign-developed technologies. We examined this issue empirically using data from 2011 to 2014 for a sample of 312 firms, classified as 'high and new-tech enterprises' located in the Hebei Province of China.

Our evidence suggest that governing R&D offshoring through market influence positively firms' innovation activity, while vertically integration of R&D offshoring through creation of R&D labs in industrialized countries has a negative effect on firms' innovation. This suggests that although domestic firms in emerging countries can access and commercialize advanced technologies developed by their R&D labs abroad (Zhou and Huang, 2014), their ability to reproduce and re-invent the technology appears more limited than if the firm would buy the technology from independent suppliers.

In addition, we find that collaboration with domestic universities tends to moderate positively the effect R&D offshoring, while employment of foreign staff moderates it negatively, especially the effect of the market-purchase of technologies. These results suggest that foreign staff may eventually foster adaptation but not innovation around the foreign-developed technologies. On the contrary, linkages with local PROs, with their own linkage network, may provide firms with support and opportunities to reinvent foreign-developed technologies and in this way improve the effect of R&D offshoring on firms' innovation activity.

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