The influence of micro-characteristics in different modes of globalization of innovation: A comparative study of Indian (Pune) and Chinese (Beijing) firms

This is a postprint version of a published article. Citations should be made to the final publication as follows:
Chaminade, C.; Plechero, M. (2013) The influence of micro-characteristics and the region in different modes of globalization of innovation A comparative study of Pune region and Beijing region. Industry and Innovation, 20(7), pp. 661-682.

Abstract Since the seminal work of Archibugi and Michie (1995) on the globalization of innovation, several authors have attempted to understand the complex relationship between innovation and internationalization. However, most tend to focus on industrialized countries, just one mode of globalization of innovation and often one traditional indicator of innovation, such as patents or R&D investment, thus ignoring the complexity and multiple aspects of the phenomenon. This paper explores empirically the linkages between different modes of globalization of innovation and firms' micro-characteristics in two of the fastest growing emerging economies. We analyze three distinct modes of globalization of innovation: the global exploitation of innovation, the global sourcing of technology, and global research collaboration. We then use primary data from Chinese and Indian firms belonging to three sectors (automotive components, software, and green biotech) to explore the differences in the ways in which the firms located in these two economies globalize their innovation activities.

Keywords: globalization, innovation, regions, firms' micro-characteristics, China, India

JEL codes: O19; P52; R11

1. Introduction

Firms have commercialized goods and services internationally for centuries and it is widely known that size, ownership and strategy, among other factors, explain the globalization of production activities (Dunning, 2001). However, the globalization of innovation activities is a more recent phenomenon (Cantwell and Piscitello, 2007; Dunning and Lundan, 2009; Le Bas and Sierra, 2002; Zanfei, 2000), which might require a different set of competences and networks than those needed to globalize production (Castellani and Zanfei, 2006). The globalization of innovation is more than the internationalization of R&D. On the one hand, it refers to truly global processes, involving knowledge flows between triad countries (the US, the EU and Japan) and non-triad countries. On the other hand, as it embraces a multiplicity of processes (Archibugi and Michie, 1995) from the global exploitation of innovation activities to the global sourcing of knowledge for innovation activities, each follows a specific direction of innovation flow and requires different competences (Plechero, 2012).

The international business (IB) literature has concentrated on the internal characteristics of firms, explaining their propensity to access international markets, and measured the globalization of innovation mainly by looking at multinational corporations (MNCs) from the triad using R&D foreign direct investment (FDI) and patent indicators (Cantwell and Piscitello, 2007; De Prato and Nepelski, 2012; Reddy, 2011; Sachwald, 2009). In contrast, scholars in the geography of innovation field have primarily been concerned with the role of the location and innovation system in which firms are embedded and with the knowledge bases prevailing in specific locations that support the firms' accumulation of resources and capabilities enabling access to foreign knowledge sources (Asheim and Coenen, 2005; Asheim and Gertler, 2005; Tödtling et al., 2011).

Understanding both the role of competences and the location of the firm in accessing different modes of globalization of innovation is yet to be the subject of investigation. This paper contributes to addressing this research gap by analyzing firm-level primary data collected in 2008 in two regions (Pune in India and Beijing in China).

The organization of this paper is as follows. Section 2 discusses the main research questions and theoretical background. Section 3 introduces the research method and the econometric model. Section 4 presents the main empirical findings related to our research questions. Section 5 provides conclusions.

2. Theoretical framework

2.1. Globalization of innovation and developing countries

In their seminal work on the global nature of innovation activities, Archibugi and Michie (1995) distinguish three modes of globalization of innovation: the global exploitation of innovation, global research collaboration and the global generation of innovation. The *global exploitation of innovation* ("global exploitation" hereinafter) refers to the international commercialization of new products or services and has its economic equivalent in the export of new products or services and in the international licensing of patents. *Global research collaboration* ("global collaboration") alludes to the joint development of know-how or innovation with the participation of partners from more than one country. This collaboration may take a variety of forms, including R&D joint ventures, R&D alliances and contractual R&D; it may involve a variety of actors, including firms, research centers, universities and governments. Finally, the *global generation of innovation* mainly refers to the location of R&D activities to a different country and is associated with R&D-related FDI. Over recent decades, scholars have collected abundant evidence of the increasingly global character of global exploitation and global collaboration, particularly by firms from industrialized economies (Chesnais, 1988; Gugler and Dunning, 1993; Hagedoorn and Schakenraad, 1990; Lukkonen et al., 1993). The global generation of innovation in the early 2000s was still a marginal phenomenon, almost exclusively relating to MNCs from developed countries locating R&D departments in another developed region of the world (Castellacci and Archibugi, 2008). However, from 2000 to 2007 the number of R&D centers owned by foreign MNCs increased by 22 times in China and by six times in India; indeed, in just one decade, these two countries changed from hosting 8% of the world's R&D centers to hosting 18% (Bruche, 2009; UNCTAD, 2005; Zheng, 2010). The increasing location of R&D centers in China and India may be explained in part by the rapid accumulation of research capabilities in these two countries (Altenburg et al., 2008), particularly in certain regions (Arora and Gambardella, 2005; Chaminade and Vang, 2008). An additional influence may be MNCs' interests in accessing these dynamic Asian markets with products particularly developed for Chinese or Indian customers (Chen et al., 2009).

In developing countries, we might expect the framework of the globalization of innovation to change at least in one respect. Firms in developing countries depend more frequently on foreign sources of knowledge for their production and innovation processes (Pietrobelli and Rabellotti, 2006). The *global sourcing of technology* ("global sourcing") thus becomes another form of globalization of innovation that is particularly important for developing countries. In this paper, we define *global sourcing* mainly as the international acquisition of inputs, such as know-how, machinery and licenses or training linked to the innovation process.

This paper investigates the role of firms' micro-characteristics and location in two regions in emerging economies for three of the four modes of globalization of innovation: global exploitation, global sourcing, and global collaboration.[1] These three modes of globalization of innovation indirectly point to a certain direction of innovation flows: from firms in these emerging economies to the rest of the world, from firms from the rest of the world to firms in these emerging economies, and bidirectional cross-border innovation flows involving both directions. Table 1 illustrates the activities included in each of the modes and the directions of innovation flows.

[1] It is not possible to analyze the global generation of innovation because of lack of available data.

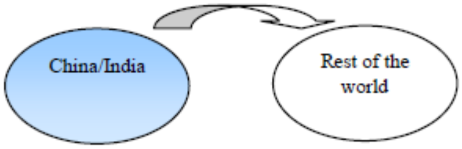
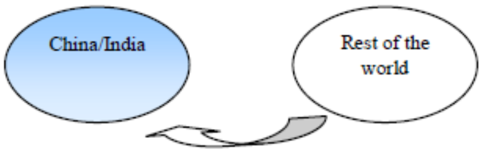
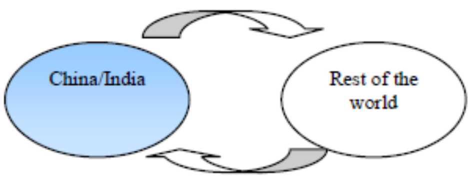
Mode of globalization of innovation	Activities included in this mode of globalization
Global exploitation of innovation (Flow of innovation from China/India) 	Use of new products or services mainly as a strategy to access international markets
Global sourcing of innovation (Flow of innovation to China/India) 	Source of technology or knowledge from an international organization (clients, suppliers, consultancy etc.) including: • International extramural R&D • International acquisition of machinery and equipment • International acquisition of other external knowledge
Global research technology (Flow of innovation from and to China/India) 	• International research collaboration with other firms • International research collaboration with other universities and research centers

Fig. 1. The three modes of globalization of innovation and directions of innovation flows considered in this paper

2.2. Context and micro-characteristics: What can sustain the globalization of innovation?

The international performance of a firm, ranging from the global exploitation to the global location of R&D facilities, may relate to a combination of the firm's internal characteristics as well as the place in which the firm is located (Blanc and Sierra, 1999).

2.2.1 Firms' micro-characteristics

Among the different theoretical approaches used to explain the international behavior of firms, the resource-based view of the firm links performance and strategies (domestic and international) to the resources and capabilities possessed by firms (Penrose, 1959; Teece, 1980; Wernefelt, 1984).

The empirical evidence in this line of research has shown that certain micro-characteristics are determinants of a firm's international performance. These include firm size and ownership structure

(Calof, 1994; Dean et al., 2000; Kleinknecht and Van Reijnen, 1992; Moen, 1999; Sousa et al., 2008; Vonortas, 1997), and firm-level competences, such as the qualification of human resources, previous international experience of managers, and educational background and ethnicity of the CEO (Nielsen and Nielsen, 2011; Sousa et al., 2008). However, they also relate to the innovative capacity of the firm. If internal capabilities are weak, the capacity to create, absorb and seek knowledge from external sources is limited (Cohen and Levinthal, 1990; Dantas et al., 2007) and thus the ability to participate in different modes of globalization of innovation will also be lower. The qualification of human resources[2] is considered to be central to building the absorptive capacity of the firm (Cohen and Levinthal, 1990) and thus it is a determinant of the firm's ability to acquire and use information and knowledge from other organizations, such as other firms, users or knowledge providers (i.e., research institutions). We might expect the qualification of human capital to have a positive effect on global research collaboration or sourcing. However, the links between the qualification of a firm's human resources and global exploitation are not that clear. Only the qualification of firm managers seems to be a significant factor explaining the international performance of a firm in terms of its exports (Sousa et al., 2008). We might then expect that:

> ***H1***. *Firms with a high percentage of qualified human resources have a higher propensity to engage in global collaboration and global sourcing.*

Technological capacity has links to innovation performance in global markets (Leonard-Barton, 1992; Prasad et al., 2001). In terms of technological capacity, we refer both to *technological investment* in innovation (intramural R&D investment) and to *technological resources*. Regarding technological investment, intramural investments in R&D are expected to serve the generation of innovation and to facilitate the acquisition of knowledge from external sources (Cohen and Levinthal, 1989; Kim, 1980;

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[2] By qualified human resources, we refer to the skills, education, experience and training of individuals (Becker, 1998, p. 1).

Veugelers, 1997). Intramural investments in R&D may therefore be considered a technological resource directly related to the firm's ability to benefit from global collaboration and arguably, to a lesser extent, from global sourcing. We might expect that:

> ***H2***. *Firms with intramural investments in R&D have a higher propensity to engage in global collaboration and global sourcing.*

The level of *technological resources* may also influence the propensity of firms to engage in global collaboration. External knowledge can be acquired more readily from firms with a lower cognitive distance from the technological frontier (Gilsing et al., 2008; Giuliani and Bell, 2005; Nooteboom, 2004). We may expect that firms in emerging economies that possess a better quality of technological resources have higher technology intensity (OECD, 1996) and hence lower cognitive distance to firms in advanced countries and a higher probability of engaging in collaboration for innovation. Moreover, we might expect that strategies for the generation of innovation, such as global collaboration, are more demanding in terms of technological competences than are those aimed at the global exploitation of innovation in foreign markets. Therefore, we expect that:

> ***H3***. *Firms with a better quality of technological resources have a higher propensity to develop global collaboration.*

2.2.2 Location

The global geography of innovation may be influenced not only by the specific firms' characteristics but also by the specific type of innovation system (local, regional or national) and industrial structure that characterize the region and country in which firms are embedded (Asheim and Gertler, 2005; Eraydin, 2005; Lundvall et al., 2009; Tödtling et al., 2011).

On the one hand, national institutions, policies and dynamics may be specific in terms of sustaining firm innovation and internationalization (Dunning and Lundan, 2009; Lundvall et al., 2009).

On the other hand, the region or the local cluster in which firms are embedded may also be important for sustaining their specific innovation and internationalization strategies (Asheim and Cooke, 1999; Bathelt et al., 2004; Maskell and Malberg, 1999; Porter, 2000). This may be particularly true in large emerging economies such as India and China where there is considerable regional diversity (Fu et al., 2012; Li, 2009; Sharma et al., 2012). We therefore expect that:

H4. *The firm's location affects its propensity to be involved in the globalization of innovation.*

We next investigate the extent to which these hypotheses are valid.

3. Research Method

3.1 Sample

The empirical analysis is based on firm-level primary data collected in 2008 through a survey in India (Pune) and China (Beijing) in three sectors (automotive components, green biotech and software). Both Pune and Beijing have specializations in these three sectors and can be considered to be knowledge hubs in their respective countries (Basant and Chandra, 2007; Chen and Kenney, 2007; Guan et al., 2009; MCCIA, 2008a, b; Sharma et al., 2012). Beijing is considered to be the scientific and technological (S&T) heart of China and thus the leading S&T region in terms of both its research infrastructure and its innovation performance (Guan et al., 2009). In total, 71 universities and 371 research institutes were located in Beijing at the end of 2003 (Beijing Statistical Information Net, 2005; cf. Chen and Kenney, 2007). Pune, on the other hand, is increasingly attracting the attention of academics, not only as a growing industrialized area but also as a growing research and innovation center in India, gradually catching up with Bangalore (Sharma et al., 2012; van Kampen and Van Naerssen, 2008; Zheng, 2010). Due to its proximity to Mumbai as well as the combined presence of foreign companies, research laboratories and good education and research institutions, MNCs consider Pune to be an attractive city in which to establish their production and, more recently, R&D activities.

In 2008, it was estimated that around 600 R&D centers of MNCs were established in India. Of those, approximately 100 were located in Pune (Zinnov, 2009). Both locations have significantly developed their international roles both as recipients and as transmitters of knowledge-intensive activities worldwide (Van Kampen and Van Naerssen, 2008; Zheng, 2010).[3] We used the same questionnaire for both locations and all sectors to ensure the complete comparability of the results.[4]

For the Pune area, we used a random sample of different databases bought from Indian industry associations, which usually cover only the formal sector. There is no economic census in Pune and thus it is difficult to estimate the total population of firms in each industry. The Mahratta Chamber of Commerce estimates the number of software companies in Pune to be around 600 (MCCIA, 2008b). Estimating the total population of automotive components and green biotech firms is difficult. In the case of automotive components, a very large number of firms belong to the informal sector. The Ministry of Science and Technology (IDC, 2008) estimates that Pune/Mumbai has around 185 *major* supplier manufacturing units in automotive parts of which the Maharashtra Industrial Corporation calculates that 145 are located in Pune.[5] No information exists on the number of firms in green biotech, but the number of food processing firms in the region (many of which are considered to be green biotech firms) is considered to be around 500 (MCCIA, 2008b). For small and medium enterprises (SMEs), in most cases, the interviewee was the owner/manager, while in larger firms the interviewee was usually the head of R&D or his/her deputy.

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[3] In 2009, we conducted a series of interviews both in Beijing and in Pune, which confirm this trend.

[4] We tested the validity of the questionnaire through a pilot survey and consultation with industry experts. The methodology used to collect the answers was partially different in the two regions primarily because of peculiarities in the local cultural approaches related to the firms (predominantly by telephone in Beijing and face-to-face in Pune).

[5] It is also estimated that there are around 6,000 informal units working with automotive components in the area, although most are repair shops.

For the Beijing area, we used a random sample extracted from different databases obtained from a market research company (Sinotrust) and from a software-testing center (CSTC) for the software industry only. There is no unique database of firms in the software industry in Beijing. According to the Statistical Yearbook of China's Electronics Information Industry 2009, there are 2,661 software firms in Beijing and 925 automotive firms, of which approximately 600 are automotive components firms, while an estimated 300 are in green biotech. The survey was conducted mainly by telephone; few interviews were face-to-face. The firms from the CSTC database were contacted by email. As in Pune, the interviewees tended to be the owners of SMEs and R&D managers of large firms.

To test the reliability of the data and the presence of non-response bias, we checked the consistency between our sample and the set of non-respondents. We assessed whether the distribution of the sample in the three industries was similar to the total population in terms of size using available statistics. Additionally, some firms were contacted *a posteriori* to check the validity of the data.

In total, 1,087 questionnaires were collected. As foreign-owned and indigenous firms may be motivated by different objectives that may affect the interpretation of the results, we excluded those firms with a foreign ownership above 30%[6] from the sample. After a first cleaning, the sample for the two specific regions was reduced to 736 firms.[7] In total, 46% of the sample consisted of firms in the automotive components sector, 22% in the green biotech sector and 32% in the software sector.

Table 1 – Main characteristics of the sample by region

	India (Pune) % of total firms	**China (Beijing)** % of total firms
Sector:		
Automotive components	53.2	31.5
Software	26.5	42.4
Green biotech	20.3	26.1

[6] This benchmark is similar to that used by Saliola and Zanfei (2009).

[7] We also excluded Chinese firms that were not located in the Beijing region.

Size:		
Large (≥ 250 employees)	12.5	13.4
Medium (between 50 and 249 employees)	28.8	39.1
Small (<50 employees)	58.6	47.5
Organizational form:		
Single	55.9	83.1
Head office	14.1	0.4
Subsidiary	30	16.5
No. of firms in the sample	498	238

The survey[8] asked firms about their structural characteristics, innovation activities, internationalization strategies, resources and capabilities, and local–global linkages. For this specific paper, we only focus on the relationships between the firms' most important micro-characteristics, location and the modes of globalization of innovation. The status of the enterprises and their activities refer to 2007.

3.2. Variables

From the answers to five survey questions, we elaborated the dependent variables related to the three specific modes of globalization of innovation discussed in section 2.1 for our econometric analysis:

a) Global exploitation of innovation. We refer to this mode of innovation when the strategy that the firms have used to access other international markets has been mainly to enter these markets with new products and services.(question 15).

b) Global sourcing of technology. We refer to this mode of innovation when firms engaged at least in one of the following activities sourced at international level: passive acquisition of extramural R&D, machinery and equipment, external knowledge and training related to innovation (question 26), or when firms have sourced technology and knowledge important for product and process innovation from external international firms and organizations (question 27).

[8] The complete survey questionnaire can be downloaded from http://globinn.circle.lu.se/our-projects-2/, in the project section: 'Emerging trends in Asia: from low-cost producers to innovators'.

c) Global research collaboration. We refer to this mode when firms engaged in international R&D collaboration with universities and research centers (question 28), or other firms (question 29).

Table 2 shows the number of firms that reported having engaged in one or several modes of globalization of innovation.

Table 2 – All possible modes in which firms participate in the globalization of innovation

Modes of globalization of innovation	**Location**		
Subcategories:	India (Pune) *(no. of firms)*	China (Beijing) *(no. of firms)*	Total
0 no global activities[a]	225	151	376
1 only global exploitation	21	12	33
2 only global sourcing	56	41	97
3 only global collaboration	6	3	11
4 only global sourcing and exploitation	20	7	27
5 only global collaboration and sourcing	20	6	26
6 only global collaboration and exploitation	2	1	3
7 all the three types of activities	13	2	15
Total[b]	363	223	586

[a] In "no global activities," we consider both firms that do not have any international activity as well as those that indicate that their sourcing or collaboration is mainly domestic or local.

[b] The total number of observations is different from 736 because of missing answers in the subcategories related to "global collaborations."

Table 2 shows that 38% of firms in Pune and more than 32% of firms in Beijing engage in at least one of the modes of globalization of innovation. Global sourcing is the most common mode pursued in both locations, which is a result one might expect in a developing country. Few firms engage in global exploitation and only a handful in global collaboration.

To avoid the possible under-representation of some of the categories described in Table 2, such as subcategories 3 or 6, we constructed two categorical dependent variables (*GLOBALKNW_source* and *GLOBALKNW_exploit*) grouping together some of the seven possible subcategories into wider sets. These sets were built to separate the choices of firms without global linkages, firms with at least global exploitation, firms with at least global sourcing, and firms with at least global collaboration.

To create *GLOBALKNW_source*, we first grouped all subcategories where research collaboration was undertaken (subcategories 3, 5, 6 and 7).[9] Then, we isolated those firms that had undertaken global sourcing. Accordingly, we grouped together subcategories 4 and 2. Subcategories 0 and 1 remained unchanged. The categorical variable equals 0 when firms engage in no global activities, 1 when firms at least engage in global exploitation (subcategory 1), 2 when firms at least engage in global sourcing (subcategories 2 and 4), 3 when firms at least engage in global collaboration (subcategories 3, 5, 6, and 7).

To build *GLOBALKNW_exploit*, we followed the same procedure as above, but to avoid isolated observations that had undertaken global exploitation. Thus, we grouped together subcategories 4 and 1 (instead of 4 and 2 as above). Subcategories 0 and 2 then remained unchanged. The categorical variable equals 0 when firms engage in no global activities, 1 when firms at least engage in global sourcing (subcategory 2), 2 when firms at least engage in global exploitation (subcategories 1 and 4), and 3 when firms at least engage in global collaboration (subcategories 3, 5, 6, and 7).

We then selected a list of independent variables related to hypotheses 1, 2, 3, and 4.

As a proxy for *qualified human resources* (H1), we used the percentage of employees with formal qualifications equal to or higher than a university degree. In general, firms in China and in India, located in knowledge hubs, have a high percentage of employees with a university degree (for example, the average in our sample is 46.3%). Therefore, the dummy variables were constructed with the aim of isolating the tails of the distribution by singling out those firms with employees without a university degree (*noEDU*) and those with more than 80% of employees with at least a university

[9] Global collaboration is considered to have a higher value than global sourcing or global exploitation as it represents an active knowledge-seeking strategy rather than passive knowledge-seeking (global sourcing) or even knowledge-exploiting (global exploitation) strategies.

degree (*highEDU*). The variable EDU indicates the central part of the distribution, i.e., firms within the two tails.[10]

We constructed two dummy variables (*intraRD and RDdep*) to proxy *intramural investment in R&D* (H2). The first variable was assigned a value of 1 if the firm engaged in intramural R&D as defined in the Oslo Manual[11] during 2007 and 0 otherwise. The second variable had a value of 1 if the firm declared the existence of an R&D department and 0 otherwise.

As a proxy for the *technological resources of the firm* (H3), we used the degree of sophistication of machinery and equipment (Padilla-Perez, 2006). In the survey, we asked firms whether their machinery and equipment were ahead, behind, or average in relation to the domestic industry. We assigned the dummy variable (*aheadMACHINE*) a value of 1 if the firm declared that their machinery and equipment were ahead and 0 otherwise.

To proxy *location* (H4), we created a dummy variable (*LOCATION*) equal to 1 if the firm was located in India (Pune) and 0 if located in China (Beijing). To capture the interrelations between the micro-characteristics of firms and the location, we also added the interaction between the variable *LOCATION* and two micro-characteristics that are usually related to firms' propensity to act in the global market: the degree of openness towards foreign markets, proxied by using the firm's percentage of exports over total sales (*OPENNESS_LOCATION*), and the specific organizational form of the firm (*SUBSIDIARY_ LOCATION*).

We also used several control variables to control for the general characteristics of the firms and industry specificity. *SUBSIDIARY, HEADOFFICE* and *SINGLE* are dummy variables assigned a value of 1 for firms of that organizational form and 0 otherwise. *DATE* indicates the specific year of the foundation of

[10] No substantial modifications of the results derive from the use of a continuous variable expressing the level of education in percentage terms.

[11] Intramural R&D is "creative work undertaken within the enterprise to increase the stock of knowledge and its use to devise new and improved products and processes."

the firm and therefore the firm age. To control for firm size, we created a dummy variable (*LARGE*) equal to 1 for firms with at least 250 employees and 0 for those with fewer than 250 employees.[12] *AUTO, SOFTWARE, BIOTECH* are dummy variables equal to 1 for firms in the indicated sector and 0 otherwise.

Appendix A presents the main statistics and the correlations between the variables.

3.3 The Econometric model

We estimate two multinomial probit models for the two categorical dependent variables described in section 3.2. We chose this model over the multinomial logit model because the Hausman test certifies that in our context the IIA assumption (Independence of Irrelevant Alternatives; Greene, 2008) is violated. As shown by Cameron and Trivedi (2005), the multinomial probit model is best suited for this case as it accounts for the links between choices, i.e., in our case, between the different modes of globalization of innovation a firm can choose.[13]

The equation for the multinomial probit models is as follows:

$$Y_{ij} = X'_{ij}\beta + \varepsilon_{ij}, j = 1, \ldots, J \quad (1)$$

where the ε_i's are distributed as a multivariate normal distribution whose covariance matrix $\sum$ is not restricted to a diagonal matrix. Y represents the categorical dependent variable with the following four outcomes j: the firm does not engage in innovation activities; the firm at least engages in global

[12] In an initial version of the model, we attempted to use three variables to distinguish large from small and medium firms separately and noticed that the only significant difference was between large and non-large companies. We thus used only the dummy "large" in our subsequent regressions.

[13] As a robust check, we created three dummy variables, each accounting for one single mode of innovation. We then ran the three separate logit models, one for each mode. We obtained results very close to those of the two multinomial probit models.

sourcing; the firm at least engages in global exploitation; the firm at least engages in global collaboration. X represents our main regressors and the controls described in the previous section.

Following Greene (2008), we can elaborate on the previous equation knowing that the term in the log-likelihood function capturing the choice of q is:

$$P[choice_{iq}] = P[Y_{iq} > Y_{ij}, j = 1, \ldots, J, j \neq q]. \quad (2)$$

Thus the probability of choosing q is:

$$P[choice_{iq}] = P\left[\varepsilon_{i1} - \varepsilon_{iq} < (X_{iq} - X_{i1})' \beta, \ldots, \varepsilon_{ij} - \varepsilon_{iq} < (X_{iq} - X_{ij})' \beta\right]. \quad (3)$$

Table 3 presents the estimated models. Model A uses the dependent variable *globalknw_source*, while model B uses the variable *globalknw_exploit*. The first row shows the possible outcomes (as opposed to the base outcome).

Table 3 – Multinomial probit models

	Global exploitation		Global sourcing		Global collaboration	
Mprobit	GLOBALKNW_source	GLOBALKNW_exploit	GLOBALKNW_source	GLOBALKNW_exploit	GLOBALKNW_source	GLOBALKNW_exploit
	Model A1	**Model B1**	**Model A2**	**Model B2**	**Model A3**	**Model B3**
LOCATION	1.044**	1.364***	0.164	-0.227	-0.422	-0.309
	[0.443]	[0.407]	[0.302]	[0.322]	[0.496]	[0.495]
AUTO	-2.349***	-2.326***	-0.956***	-0.651**	-1.972***	-1.997***
	[0.469]	[0.399]	[0.305]	[0.323]	[0.464]	[0.463]
BIOTECH	-0.953**	-1.214***	-1.208***	-1.016***	-1.117***	-1.118***
	[0.416]	[0.378]	[0.323]	[0.336]	[0.405]	[0.405]
OPENNESS	0.038***	0.041***	0.033***	0.030***	0.035***	0.035***
	[0.009]	[0.009]	[0.008]	[0.008]	[0.009]	[0.009]
HEADOFFICE	-0.256	-0.063	0.808**	0.939**	0.253	0.151
	[0.660]	[0.524]	[0.374]	[0.384]	[0.703]	[0.696]
SUBSIDIARY	0.342	0.861*	0.326	0.139	-0.3	-0.278
	[0.596]	[0.497]	[0.407]	[0.423]	[0.628]	[0.628]
DATE	-0.032*	-0.009	0.011	0.005	-0.030**	-0.031**
	[0.017]	[0.014]	[0.011]	[0.011]	[0.015]	[0.015]
LARGE	-0.281	0.397	0.701**	0.554*	1.025***	1.039***
	[0.502]	[0.367]	[0.283]	[0.291]	[0.353]	[0.352]
noEDU	-0.105	0.347	0.214	0.124	0.1	0.158
	[0.567]	[0.436]	[0.292]	[0.296]	[0.510]	[0.505]
highEDU	-1.177***	-1.093***	-0.395	-0.225	-0.746**	-0.759**
	[0.394]	[0.343]	[0.278]	[0.292]	[0.374]	[0.373]
aheadMACHINE	0.986***	1.176***	0.791***	0.695***	0.637**	0.679**
	[0.330]	[0.295]	[0.229]	[0.237]	[0.319]	[0.319]
intraRD	0.305	0.633*	0.153	-0.033	0.632*	0.672*
	[0.375]	[0.329]	[0.234]	[0.239]	[0.372]	[0.372]
RDdep	-0.033	-0.043	-0.014	-0.069	-0.118	-0.12
	[0.385]	[0.338]	[0.256]	[0.264]	[0.375]	[0.374]
OPENNESS_LOCATION	-0.043***	-0.030***	-0.017*	-0.017*	-0.008	-0.009
	[0.014]	[0.011]	[0.010]	[0.010]	[0.012]	[0.011]
SUBSIDIARY_LOCATION	-0.879	-1.534**	-0.239	0.238	1.481**	1.347*
	[0.758]	[0.635]	[0.498]	[0.518]	[0.750]	[0.747]
Constant	62.220*	16.993	-23.43	-11.648	58.706*	59.173*
	[33.279]	[28.432]	[22.572]	[22.840]	[30.886]	[30.633]
N	484	484	484	484	484	484
Ll	-368.898	-380.451	-368.898	-380.451	-368.898	-380.451
chi2	152.773	161.778	152.773	161.778	152.773	161.778
P	0	0	0	0	0	0

*p<0.10, **p<0.05, ***p<0.01. Standard errors in parenthesis. Baseline: no global activities

4. Empirical findings

H1. *Firms with a high percentage of qualified human resources have a higher propensity to engage in global collaboration and global sourcing.*

The test leads to an opposite result for hypothesis 1. Our results show that a high percentage of qualified human resources employed in the firm is not positively related to any of the modes of globalization of innovation, but is negatively related to global exploitation and global collaboration. One possible explanation is that firms with higher percentages of qualified human resources are also more capable of developing their own technology in-house and rely less on international linkages. The Community Innovation Survey (Eurostat, several years) consistently shows that the most important source of information for innovation is the firm's employees; external sources of knowledge are secondary to internal ones. This is also consistent with recent evidence that shows approximately 60% of firms in both developed and developing countries produce most of their technological inputs in-house (Chaminade, 2011).

H2. *Firms with intramural investments in R&D have a higher propensity to engage in global collaboration and global sourcing.*

The test only marginally confirms hypothesis 2. In our econometric analysis, we observe a significant positive relationship between intramural R&D activities (intraRD) and *global collaboration* (models A3 and B3) and *global exploitation* (model B1). However, we do not find any evidence supporting our hypothesis of a positive relationship between intramural R&D investments and *global sourcing* (in line with the double role of R&D suggested by Cohen and Levinthal, 1989).

We also observe no significant relationship between having an R&D department and the two modes of globalization of innovation investigated in the second hypothesis. This suggests that although having R&D investments may be important for global collaboration and global exploitation, the degree of formalization of those activities in the form of a specific R&D department is not especially important.

H3. *Firms with a better quality of technological resources have a higher propensity to develop global collaborations.*

The tests confirm hypothesis 3, using the level of sophistication of machinery and equipment as a proxy for technological resources. Firms that have a higher degree of sophistication of machinery and equipment show a significant relation not only with global collaboration but also with global exploitation and global sourcing.

Regarding the other micro-characteristics of the firm, the econometric analysis shows that firms with a higher degree of openness to the market also engage in all the modes of globalization of innovation. Knowledge of international markets through exports not only facilitates the commercialization of innovation (global exploitation) but also global sourcing and global collaboration. As expected, headquarters and large firms are more likely to engage in global sourcing or collaboration in their innovation activities.[14]

One result is particularly interesting: Younger firms are more likely to engage in global collaboration compared with established firms. This may be because these firms lack well-established connections at the local or national levels (which pushes them to go abroad in the search of partners) or that they are keener on tapping into international sources of knowledge. This should be the subject of further research.

[14] We also observe important sectoral differences. Firms in the software industry are more likely to pursue development in all three modes of globalization of innovation when compared with those in the automotive components and green biotech sectors (the coefficients for the variables *AUTO* and *BIOTECH* are always negative and significant, showing that moving from the software sector, the baseline dummy, has a negative effect).

H4. *The firm's location affects its propensity to be involved in the globalization of innovation.*

For *global exploitation*, we observe that location matters. Being located in China (Beijing) rather than in India (Pune) provides a lower probability of the firm being involved in global exploitation.[15] This confirms Guan et al.'s (2009) finding that firms located in China, and in particular in the Beijing region, tend to confine their innovation activities more to the domestic sphere. In other words, firms in India (Pune) commercialize their innovation in global markets more than firms in China (Beijing) do so. When examining the interaction between the variable LOCATION and the variables SUBSIDIARY and OPENNESS, we observe in closer detail a certain complementarity between the role of location and firm-specific characteristics. We see that having previous experience in international markets and being a subsidiary have less impact on the probability of carrying out global exploitation activities if the firm is located in the Pune region.[16]

For *global collaboration*, the fact that in India (Pune) more firms are involved in this mode of globalization of innovation (11.29% compared with 5.38% in Beijing) seems to be explained primarily by the specific characteristics of firms. The variable LOCATION is not significant in models A3 and B3, and therefore location does not explain the variance in the sample *per se*. Nevertheless, we observe that being a subsidiary is not enough to foster *global collaboration* unless the firm is also located in India (Pune). In both models related to global collaboration, A3 and B3, SUBSIDIARY is not significant as a direct regressor but it has a significant and positive effect when interacting with the regional dummy.

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[15] The variable LOCATION is positive and significant in models A1 and B1 of Table 4. Moreover, the percentage of sample firms in Pune involved in this activity is higher (11.45%) compared with that in Beijing (9.24%).

[16] The variables OPENNESS and SUBSIDIARY have positive direct effects, but negative interaction effects with the location variable (OPENNESS_LOCATION; SUBSIDIARY_LOCATION) for global exploitation. However, there is only partial confirmation for the effect of subsidiary in the multinomial probit model B1.

For *global sourcing,* we only observe that this activity remains a common strategy for firms independent of their specific locations (the percentage in our sample converges toward 24% in both regions).[17] The analysis thus confirms hypothesis 4 on the specific role of location, but only for global exploitation and global collaboration. It also shows the interplay between the micro-characteristics of the firm and the area in which firms are located when explaining the different propensities to engage in different modes of globalization of innovation. Table 5 summarizes the main empirical results.

Table 5 – Summary of main results

Mode of globalization of innovation	**Global exploitation of innovation**	**Global sourcing of technology**	**Global research collaboration**
Percentages (of total answers)	11.45% of firms in India (Pune) 9.24% of firms in China (Beijing)	23.90% of firms in India (Pune) 24.79% of firms in China (Beijing)	11.29% of firms in India (Pune) 5.38% of firms in China (Beijing)
Factors affecting the modes of globalization of innovation	Location (+) Micro-characteristics: • High qualification of human resources (-) • Intramural R&D (+) • Degree of sophistication of machinery and equipment (+) • Openness (+) Sector: Software (+)	Micro-characteristics: • Degree of sophistication of machinery and equipment (+) • Openness (+) • Head office (+) • Large firm (+) Sector : Software (+)	Location but only in conjunction with micro-factors: (+) Micro-characteristics: • High qualified human resources (-) • Intramural R&D (+) • Degree of sophistication of machinery and equipment (+) • Openness (+) • Younger firm (+) • Large firm (+) • Subsidiary (in Pune) (+) Sector: Software (+)

As a robustness check we also split our sample in two subsamples according to the two different locations of the firms. We re-run the same regressions, slightly simplified to cope with emerging computational infeasibilities, and found that location has a clear role in

[17] The interaction OPENNESS_LOCATION is weak: We checked the significance of this interaction using a logit model that had as its dependent variable global sourcing (1 = the firm performs that specific mode; 0 = the firm does not). The interaction in this case was not significant.

determining the differences between Chinese and Indian firms' behaviors. Not only the coefficients of OPENNESS and SUBSIDIARY appear to be different in the two subsamples, but also other coefficients such as the ones related to sector variables (*AUTO, BIOTECH*), the quality of firm's technological resources (*aheadMACHINE*), age (*DATE*) and size (*LARGE*). This further confirms our findings for global exploitation and global collaboration, and enriches our analysis because it shows that the location of the firm is an important factor to consider when evaluating the firms' micro-characteristics and strategies (Pietrobelli and Rabellotti, 2011; Srholec, 2011). Indeed our analysis of the subsamples uncovers that the main effect of several micro-characteristics is coupled with a location-specific effect.

5. Conclusion

Using firm-level data collected in India and China in 2008, this paper investigates empirically for the first time multiple patterns of the globalization of innovation of firms located in two important emerging economies. In doing so, it addresses important gaps in the literature on the globalization of innovation, such as the focus on home regions in industrialized countries or the investigation of single modes of globalization of innovation mainly related to MNCs' activities abroad. In terms of theoretical contributions, the paper examines aspects considered in both the economic geography and IB literature to show that there is a combined effect of firm-level factors (the focus of the IB literature) and location (the focus of the economic geography literature) on the capacity to develop global collaboration and global exploitation.

A first set of findings concerns the predominance of different modes of globalization of innovation in the two economies. We found that *global sourcing*, i.e., sources of technology or knowledge from an international organization, is the most common strategy pursued by the firms in the sample. It seems that few micro-characteristics relate to global sourcing, and we could not find any significant relationship between location and global sourcing. Therefore, global sourcing still seems to constitute a necessity rather than an option for firms in developing countries as these firms will buy from abroad almost independent of their location or characteristics.

Nevertheless, we also found that a number of firms in these two regions are starting to undertake both *global research collaboration* and the *global exploitation of innovation*. Firms located in India (Pune) are more involved than firms located in China (Beijing) in these two modes of globalization of innovation. In particular, we found that the interplay between firm-level factors and location might explain the different propensities of firms to engage in these two modes of globalization of innovation, although it is not possible to explain if the observed effect is due to regional or national characteristics based on the current data. Finally, the micro-characteristics of the firms and also their difference in the two locations seem to be more relevant for explaining global collaboration. Several factors matter for firms to engage in global collaboration, namely, investing in intramural R&D, having machinery and equipment ahead of the average of the domestic market, previous experience in international markets, and being a subsidiary or a young or large firm.

As the analysis relates to the first survey of this kind, the paper shows some limitations, particularly related to the methodology employed in the study. As is often the case in developing countries, it is not possible to calculate the total population of firms with full accuracy and thus it is difficult to say beyond doubt what is representative in terms of the sample or the response rate. We also acknowledge the limitations of some of the indicators used for the analysis. Any questionnaire based on self-report data has a certain degree of subjectivity as has been acknowledged widely in studies based on CIS data. We aimed to minimize this by using indicators and questions based on the Oslo Manual and including all definitions in the questionnaire. More standardized and robust proxies would definitely be required to further confirm the results related to some of the hypotheses.

The findings confirm some of our hypotheses, qualify others, and reveal several results that deserve further research. While the globalization of innovation is important for a number of firms, most of them have a markedly local or domestic character. Whether this is a result of a lack of capabilities and strategies at the firm level or the quality of institutions and innovation systems at national and/or regional levels is yet to be the subject of research. The interwoven effects between factors at the regional, country and micro levels needs further investigation as comparable data across regions in India and China becomes available. Developing new and stronger indicators for all modes of globalization of innovation and increasing the geographical coverage of the study to other developing country regions should also be encouraged.

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Appendix A

Descriptive statistics and correlations between the main variables

Variable	Obs	Mean	Std. Dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) GLOBALKNW_source	586	0.7508532	1.074669	0	3	-							
(2) GLOBALKNW_exploit	586	0.6416382	0.9894694	0	3	0.9045*	-						
(3) GEXPLOIT	736	0.107337	0.3097517	0	1	0.3857*	0.6299*	-					
(4) GSOURC	736	0.2418478	0.4284938	0	1	0.8732*	0.6453*	0.2449*	-				
(5) GRDCOLLAB	586	0.0904437	0.2870614	0	1	0.6605*	0.7522*	0.1917*	0.3450*	-			
(6) LOCATION	736	0.6766304	0.4680805	0	1	0.0767	0.0998*	0.0333	-0.0098	0.1001*	-		
(7) AUTO	736	0.4619565	0.4988896	0	1	-0.2823*	-0.3349*	-0.2245*	-0.1542*	-0.2323*	0.2036*	-	
(8) BIOTECH	736	0.2214674	0.4155168	0	1	-0.0731	-0.0467	-0.0792*	-0.1484*	-0.0188	-0.065	-0.4942*	-
(9) SOFTWARE	736	0.3165761	0.4654568	0	1	0.3476*	0.3825*	0.3113*	0.2978*	0.2551*	-0.1602*	-0.6306*	-0.3630*
(10) OPENNESS	736	10.88043	24.52852	0	100	0.4309*	0.4232*	0.2250*	0.3806*	0.3356*	0.0769*	-0.2311*	-0.019
(11) HEADOFFICE	733	0.0968622	0.295972	0	1	0.0231	-0.0038	-0.0246	0.0082	-0.0313	0.2158*	0.0848*	0.0714
(12) SUBSIDIARY	733	0.2564802	0.4369881	0	1	0.1817*	0.1714*	0.0377	0.1337*	0.1961*	0.1440*	-0.0247	-0.0098
(13) SINGLE	733	0.6466576	0.4783343	0	1	-0.1811*	-0.1559*	-0.0192	-0.1272*	-0.1624*	-0.2650*	-0.0299	-0.0352
(14) DATE	703	1995.7	10.30736	1926	2008	0.014	0.0059	0.0329	0.0303	-0.0257	-0.1339*	-0.2119*	-0.069
(15) LARGE	734	0.1280654	0.3343905	0	1	0.2500*	0.2439*	0.1324*	0.2336*	0.2363*	-0.0132	-0.0698	0.0405
(16) noEDU	694	0.2233429	0.4167867	0	1	-0.1094*	-0.1441*	-0.0917*	-0.0463	-0.1005*	0.2071*	0.4646*	-0.2481*
(17) EDU	694	0.5461095	0.4982285	0	1	0.1128*	0.1617*	0.1298*	0.0722	0.1101*	0.0496	-0.0308	0.0750*
(18) highEDU	694	0.2305476	0.4214871	0	1	-0.025	-0.0494	-0.0628	-0.0396	-0.031	-0.2634*	-0.4230*	0.1567*
(19) aheadMACHINE	684	0.2397661	0.4272531	0	1	0.2121*	0.2056*	0.2425*	0.2131*	0.0603	-0.3003*	-0.1354*	-0.0095
(20) intraRD	736	0.5054348	0.5003105	0	1	0.0827*	0.1012*	0.1411*	0.0573	0.0288	-0.2481*	-0.2554*	0.1284*
(21) RDdep	705	0.5248227	0.499738	0	1	0.1666*	0.1654*	0.1109*	0.1331*	0.0966*	-0.4306*	-0.3568*	0.1252*
Variable (continue)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	**(18)**	**(19)**	**(20)**	**(21)**
(9) SOFTWARE	-												
(10) OPENNESS	0.2647*	-											
(11) HEADOFFICE	-0.1542*	-0.0095	-										
(12) SUBSIDIARY	0.0352	0.1703*	-0.1923*	-									
(13) SINGLE	0.0633	-0.1497*	-0.4430*	-0.7945*	-								
(14) DATE	0.2882*	0.0241	-0.2072*	-0.0422	0.1662*	-							
(15) LARGE	0.0388	0.1201*	0.0273	0.2466*	-0.2421*	-0.1746*	-						
(16) noEDU	-0.2700*	-0.1068*	0.0292	-0.0038	-0.0148	-0.0658	-0.0374	-					
(17) EDU	-0.0353	0.0549	-0.0247	0.0549	-0.0345	-0.057	0.043	-0.5882*	-				
(18) highEDU	0.3088*	0.0407	0.0003	-0.061	0.0554	0.1307*	-0.0139	-0.2935*	-0.6004*	**-**			
(19) aheadMACHINE	0.1553*	0.0579	-0.002	-0.0133	0.0134	-0.0514	0.2065*	-0.0751	0.0373	**0.0303**	**-**		
(20) intraRD	0.1591*	-0.034	0.0458	0.0162	-0.0431	0.0255	0.0947*	-0.2829*	0.1003*	**0.1612***	**0.2326***	**-**	
(21) RDdep	0.2725*	0.1189*	0.0668	-0.0251	-0.0182	0.0435	0.1599*	-0.3239*	0.0762*	**0.2303***	**0.3143***	**0.5000***	**-**

***P<0.05**