A Dynamic Comparative Analysis of International Innovation Networks in Emerging Market MNCs

Abstract

This paper compares the international innovation strategies of emerging market multinationals (EMNCs) with those of developed country multinationals (DMNCs). More specifically, we analyze the patent outcomes related to the use of international innovation networks of EMNCs in developed markets compared with those of DMNCs in emerging markets. We explore the convergence and volatility patterns in patent generation within these international innovation networks, considering the use of overseas R&D affiliates and the outcomes of interactions between foreign R&D affiliates and home headquarters for generating patents over a 20 year period. Our findings are broadly supportive of the idea that the trends in the volume and volatility of patents generated from the underlying international innovation networks used by EMNCs are converging with those of DMNCs. This is in line with the predictions of a number of current international business theories regarding EMNC international expansion.

Key Words: R&D, internationalization, innovation, MNEs, emerging markets

1. Introduction

The international innovation activities of MNCs have surged in recent years (von Zedtwitz, 2005; Dunning and Lundan, 2009; Wang and Kafouros, 2009). Developed country MNCs (DMNCs) have increasingly invested in research and development (R&D) activities in *emerging markets*, such as Brazil, Russia, India, and China (the BRICs) (UNCTAD, 2005; UNCTAD, 2013; Barnard and Cantwell, 2007). Conversely, since the 1990s, emerging market multinationals (EMNCs) have significantly expanded and scaled up their innovation activities in *developed countries* (Dunning and Lundan, 2009; Barnard and Cantwell, 2007; Wang and Kafouros, 2009; Meyer *et al*., 2011). The creation and development of EMNC' international innovation networks (hereafter IINs), moreover, is widely conjectured to involve strategic asset seeking (SAS) (Matthews, 2006; Luo and Tung, 2007), in which EMNCs try to augment their comparatively weak firm specific assets (FSAs) (or 'ownership advantages') (Rugman and Verbeke, 1990; Dunning, 1988).

This trend has led many scholars to question whether the OLI paradigm adequately explains EMNCs (Child and Rodigues, 2005; Luo and Tung, 2007; Matthews, 2006). At the heart of this conceptual battleground lies the issue of whether EMNCs have the requisite firm-level ownership advantages to absorb developed market strategic assets of DMNCs (Cuervo-Cazurra, 2012; Narula, 2012; Hennart, 2012), as well as the absorptive capacity to manage the challenges of multiple-embeddedness that such IINs bring (Meyer *et al.*, 2011; Figueireido, 2011). To date, however, there has been surprisingly little systematic empirical research on the *outcomes* of EMNC SAS related OFDI or, more generally, how EMNCs manage their

IINs. The strategies and mechanisms used to generate these outcomes (i.e. the types of IINs used), or whether EMNCs use different mechanisms and strategies to those of DMNCs, have not been greatly explored. These lacunae are surprising in light of the growing theoretical literature exploring whether and how EMNCs are different to DMNCs and in turn whether new conceptual models specific to EMNCs are needed to explain their behaviours (Hennart, 2012; Narula, 2012; Cuervo-Cazurra, 2012).

To address some of these questions, in this paper we compare the IIN mechanisms used to generate patents in EMNCs and DMNCs. Specifically, our comparison here is between EMNCs conducting innovation activities in developed countries and DMNCs entering emerging countries (in this case the BRICs), the rationale for which is later explained (see methods section). We first layout the conceptual background and develop our hypotheses. Second, we describe the research method and constructs used. Third, we present our empirical results. The fourth section discusses their implications, followed by the conclusion.

2. Conceptual background and Hypotheses

The role of innovation, intangible asset creation and knowledge seeking FDI has become a pivotal issue in recent conceptual discussion of EMNCs. This is because the rise of EMNCs has brought into question, for some, the relevance of the OLI paradigm, a mainstay of International Business theory (Dunning, 1988). Some have questioned whether EMNCs possess the requisite firm specific assets (FSAs) for successful FDI. They argue, therefore, that their rapid FDI growth, particularly to developed markets, cannot be well explained by OLI type thinking (Matthews, 2006; Luo and Tung, 2007). Instead, it is argued EMNCs try

to rapidly acquire technologies and various other intangible assets, primarily from psychically distanced developed markets, so as to augment their own FSAs via SAS. At the heart of the EMNC debate lies the question of whether EMNCs can absorb and develop intangible strategic assets via FDI to developed markets, and whether the portfolio of IINs used in their strategies are fundamentally different from those of DMNCs (Cuervo-Cazurra, 2012; Narula, 2012; Ramamurti, 2012). Extending some of these ideas to IINs, we first consider how MNCs face the 'dual network' problem and how a set of asymmetric forces, particularly ones related to country specific assets (CSAs)(Rugman and Verbeke, 1990) impinge on and shape EMNC and DMNC's international innovation strategies in different ways. Secondly, we consider how both CSAs and FSAs may differentially affect volatility in the IINs created by EMNCs and DMNCs.

2.1 The dual network problem and convergence in the evolutionary paths of IINs in EMNCs and DMNCs

Both DMNCs and EMNCs have powerful incentives to set up overseas R&D subsidiaries (Gilsing *et al*., 2008). As Meyer *et al* (2011: 241) note, MNCs are becoming more knowledge driven and competition forces them 'to cultivate knowledge assets in what were considered non-traditional locations'. In doing so, they can exploit the international pool of research talent. For DMNCs, high quality low cost R&D personnel in some emerging markets are an attraction (Reddy, 1997; Barnard and Cantwell, 2007). For EMNCs, as noted, such investments represent important channels to access the more advanced technologies of developed countries. In undertaking such investments both kinds of MNCs are involved in cooperative learning, involving assimilation of local culture, norms and conventions. This

requires MNCs to also ‘embed’ within local innovation systems, so as to adapt products or services to local tastes and absorb locally created ideas (Nonaka, 2007; Ghoshal and Bartlett, 1988; Meyer et al.. 2011).

The IIN strategies of MNCs have been widely discussed in the international innovation literature, including issues such as: the role of inter-firm cooperation (Hagedoorn, 1993); decentralized R&D governance versus centralized R&D activities within MNCs (Cantwell, 1995; Florida, 1997); the network-based notion of R&D and knowledge-based activities (Narula and Hagedoorn, 1999); and the modes of overseas R&D and headquarter interaction (Narula and Zanfei, 2005). The unifying framework of the ‘double network’ structure (Zanfei, 2000) (or the ‘dual network’ problem as it is referred to by others (Meyer, Mudambi and Narula 2011: 242)), however, is most relevant for our consideration of IINs. It argues MNCs deploy internal networks, interconnecting the innovation activities of a growing number of overseas R&D subsidiaries located in different countries, as well as external networks, through which these R&D affiliates set up linkages with foreign firms and institutions to gain access to local innovation systems. Thus the ‘dual network’ approach, involving challenges of both internal and external embeddedness, represents a global knowledge sourcing, integration, and exploitation system (Dunning and Lundan, 1998; Ghoshal and Bartlett, 1988; Zanfei, 2000).

From the technological learning perspective, the dual network involves two kinds of learning processes: experiential learning and connectivity within the MNC network to transfer knowledge (internal embeddedness); and also cooperative learning with outside partners (external embeddedness) (Ambos, Ambos, and Schlegelmilch, 2006; Kogut and Zander, 2003; Tsai *et al*., 2009; Meyer *et al*. 2011). Therefore, MNCs can tap into local knowledge bases

through cooperation with a variety of external parties, and leverage self-knowledge stock in the internal knowledge network, as well as self-experience accumulation during the "learning-by-doing" process (Hitt, Li, and Worthington, 2005). To do so, however, involves leveraging localized knowledge networks via embeddedness within the local milieu and internal embeddedness within MNE networks (Meyer et al, 2011). Thus, a fully integrated MNC IIN governance portfolio involves: (1) management of overseas R&D affiliates for patent generation, involving effective external embedding in host locations to appropriate knowledge spillover, and; (2) interactions between overseas R&D affiliates and home headquarters or other affiliates, or internal embedding (Meyer, *et al.*, 2011).

The choice and evolution of the organizational mechanisms used in implementing IIN activities relies on various factors, including initial firm' endowments (i.e. FSAs), the home and host countries' location advantages (CSAs), as well as their dynamic co-evolution and interaction. MNCs IIN governance portfolios evolve in a co-aligned fashion with these dynamic forces (Hitt, Li, and Worthington, 2005; Dunning and Lundan, 2009; Zhang and Baden-Fuller, 2010). Or, as Narula (2012: 189) puts it: 'firms are constrained by the kinds of assets they can absorb, acquire, and internalize by the extent of their absorptive capabilities…which, in turn, are shaped by their external environment'. Home, as opposed to host country characteristics, moreover, are considered to be particularly important in shaping EMNC' FDI (Meyer *et al.*, 2011; Narula, 2012; Cuervo-Cazurra, 2012; Hennart, 2012), where home country institutions are considered 'idiosyncratic' (Lahiri *et al*., 2012). Extensions of the OLI framework applied to EMNCs, however, also stress that while the ownership advantages of EMNCs and the resultant differing internationalization patterns are initially 'strongly shaped by location conditions in the country of origin', the influence of home CSAs will 'gradually diminish over time' (Cuervo-Cazurra, 2012: 163). This is because as EMNCs,

which are typically also infant MNCs, become more internationalized, they become less reliant upon their home country (Cuervo-Cazurra, 2012).

Furthermore, as the domestic CSAs of EMNCs also evolve in line with increasing international integration and conformity to global institutions (for instance, China's entry to WTO), so too do domestic CSAs in emerging countries start to become more aligned with those of developed countries. Extensions of the OLI framework therefore predict that the ownership advantages of EMNCs and DMNCs differ in large part because of the features of the location conditions of the country of origin (Narula, 2012; Hennart, 2012) and the 'asymmetries' of these with developed markets (Madhok and Keyhani, 2012), so resulting in 'differing internationalization patterns' (Cuervo-Cazurra, 2012: 163). As EMNCs internationalize the influence of their domestic CSAs diminishes and convergence between EMNCs and DMNCs may start to take place. This is a dominant strand of thought among those that argue the OLI model can explain EMNCs if the idiosyncratic nature of EMNC domestic CSAs is accounted for (Narula, 2012; Cuervo-Cazurra, 2012; Hennart, 2012; Ramamurti, 2012).

Just as the influence of CSAs on MNCs may evolve and their influence on IINs change, EMNC FSAs may also evolve over time, eventually allowing them to better exploit their IINs. Zanfei (2000) notes, as does Narula (2012) and Meyer *et al*. (2011), that even for DMNCs considerable effort and investment is required to run dual networks and prevent them from collapsing. To fully exploit IINs that involve multiple-embeddedness is a major challenge for EMNCs (Narula, 2012). High absorptive capacity, for example, requires considerable organizational and transaction-type ownership assets 'to effectively engage in reverse knowledge transfer' *(*Narula, 2012: 195). Compared to DMNCs, which are comparative

veterans, EMNCs as newcomers are likely to struggle initially with the challenges of multiple-embeddedness, particularly in their infant stages of R&D internationalization (Meyer *et al*. 2011). While they aspire to learn gradually how to unlock the full value of such subsidiaries, involving reverse knowledge flows throw internal embeddeness, this takes time. In the course of organizing international innovation activities, however, EMNCs can gradually accumulate such knowledge (Narula, 2012; Cuervo-Cazurra, 2012). They may acclimatize to the global operational environment and learn from their DMNC counterparts. Indeed, given the increasing competition in their domestic markets with DMNCs and other firms, global knowledge sourcing and expansion becomes increasingly important for latecomer firms. Thus, they have strong incentives to rapidly improve their global IIN organizational mechanisms via learning-by-doing, or learning-by-using (von Hippel, 1988), which consequently transform their organizational mechanisms towards those of the IINs employed by DMNCs.

To summarize, emerging country domestic CSAs are different to those in developed markets and these may influence the type of IIN strategies EMNCs initially follow. Over time, however, these CSA related differences narrow. EMNCs, moreover, initially also lack experience in managing and operating complex IINs and overcoming the challenges of dual embeddedness (Figueireido, 2011: Meyer *et al*. 2011). But again, over time, these FSA related differences may narrow as EMNCs gain experience. As such, a dominant strand of thought argues 'there are few obvious reasons to predict that DCMNEs are of unique character, and as they evolve as MNEs, the observable differences between DC [i.e EMNCs] MNEs and advanced economy MNEs will diminish' (Narula, 2012: 200). This leads to our first hypothesis:

Hypothesis 1: Over time the outputs from and nature of the IINs used by EMNCs in developed markets will converge with those of DMNCs in emerging markets.

2.2 Factors affecting the volatility of the portfolio of IIN strategies used by EMNCs and DMNCs

How do EMNC' CSAs and FSAs impact on success or failure of IINs and how does this translate itself into the stability or otherwise of the IIN strategies followed? As already noted, the initial FSAs of all MNCs, but particularly *infant* EMNCs, are shaped by domestic CSAs: 'The initial home conditions from which it begins to internationalize shapes its assets and, therefore, the character (in terms of geographical spread, sector, and mode of investment) of its outward activity' (Narula, 2012: 200). Many EMNCs in comparison to DMNCs, moreover, are also 'infant MNCs' (Cuervo-Cazurra, 2012). The CSAs faced by infant EMNCs are also considered to be limited when compared to those of an equivalent infant DMNC (Cuervo-Cazurra, 2012; Narula, 2012) and the influence of home CSAs on the volatility of the IINs used by EMNCs may, therefore, also be important. For example, while it is possible that the IINs of some EMNCs may benefit from their unique domestic CSAs, such as imperfect domestic institutions (for example, special ownership types (Cuervo-Cazurra, 2012), and access to favorable 'complementary local resources', a sub-set of location advantages only available to EMNCs in their home market (Hennart, 2012)), many, arguably the majority, do not. The pervasive lack, for example, of efficiently functioning capital markets, often forces EMNCs to substitute for these via business group creation to compensate for inefficient or

non-existent domestic markets, known as 'institutional voids' (Khanna and Yafeh, 2007). Inefficient markets combined with insufficient resources to sustain their global knowledge sourcing and innovation activities (and run dual networks) may create volatility in the types IINs used and their outputs. Thus, when facing domestic market imperfections (for example, imperfect capital markets) they will be more likely to be forced into restructuring their foreign R&D affiliates (i.e. closure, change of function) (Chen and Tong, 2003). This may lead to greater volatility in EMNC' IINs. Those EMNCs, moreover, that benefit from government support and accompanying preferential domestic complementary local resources (Hennart, 2012), may not have an explicit global strategy (Deng, 2009). Owing to poor corporate governance, for example, reckless empire building and excessive outward FDI may be encouraged by these types of domestic supports (Morck *et al.*, 2008). This can imply their R&D expansion and development of IINs is whimsical, owing to poor corporate governance, there being little clarity in the final IINs desired. This, therefore, may also lead to greater volatility in the IIN mechanisms used and their outputs. These are examples of how location bound CSAs can impact on the development of IINs in EMNCs, in turn leading to greater volatility in the type of IIN strategies they follow and outputs from them.

While DMNCs may benefit from more favorable domestic CSAs, another influential factor helping stability in their IINs relates to the fact that they are also typically more internationalized than their EMNC counterparts. As a result, they are also less dependent on, and restricted by, their home country CSAs (Narula, 2012). These therefore play 'a limited role' in their behavior (Cuervo-Cazurra, 2012; 162). Another way of looking at this, and linking it to IIN volatility, is that DMNCs are able to engage more actively in institutional exit (Witt and Lewin, 2007). Such international exit strategies can act as hedging mechanisms,

mitigating DMNC exposure to any unfavorable domestic CSAs. This greater geographical diversification allows DMNCs to benefit from 'a wider variety of non-home country influences' than EMNCs (Narula, 2012: 195), so DMNCs effectively engage in a form of insurance against unfavorable CSAs. This, in turn, may translate itself into greater stability in the implementation of firm-level strategies, including those related to IINs. While EMNCs also attempt to engage in these institutional arbitrage strategies, owing to their generally earlier stages of development and sometimes restrictive outward investment policies, they are comparatively less internationalized than DMNCs (Boisot and Meyer, 2008).

Finally, taking an alternative perspective on EMNCs' internationalization, the strategy literature has posited that EMNCs are innately more entrepreneurial and risk taking in the process of SAS. The strategic entrepreneurship of EMNCs originates, it is argued, from the unique asymmetries they face with DMNCs, in terms of historical and institutional differences (i.e. CSAs) (Madhok and Keyhani, 2012). In the search for advantage creation through strategic entrepreneurship when firms possess mainly 'ordinary resources', they are driven into 'creating something from nothing' - i.e. taking significant risks (Madhok and Keyhani 2012: 29). They thus engage in high-risk, discovery type investments to attempt to address the asymmetries they face to appropriate rents: 'entrepreneurial rents originate from the inherent and genuine uncertainty that makes the future not only unknown, but unknowable… 'rarely will entrepreneurs be able to see "the end from the beginning"' (Madhok and Keyhani 2012: 26). In other words, EMNCs are likely to engage in high risk strategies, leading to comparatively high volatility in the IINs employed and their outputs.

To summarize, for reasons, related to FSAs, CSAs and the interaction of the two (Cuervo-Cazurra, 2012; Narula, 2012), as well as owing to greater 'learning by doing' required by EMNCs and the role of asymmetries and entrepreneurial rents (Madhok and Keyhani, 2012) , we expect greater experimentation in the structuring of internal and external embeddedness, involving higher failure rates and greater volatility in the IINs employed and their outputs. This leads to our second hypothesis:

Hypothesis 2: The portfolio of IIN mechanisms used by EMNCS in developed markets exhibits greater volatility than those of DMNCs in emerging markets.

3. Methods

3.1 Data collection and sample selection

Finding useable data to investigate international innovation is problematic. Historically, the international innovation activities of countries has often been studied at the national level using patent data (von Zedtwitz, 2005; Chen, 2003; Bas and Sierra, 2002; Ma and Lee, 2008). Using R&D expenditure, by contrast, has been considered troublesome, because quantitative measurements of R&D investments abroad are missing and R&D expenditures are not often reported in official statistics on FDI (Griliches, 1998; Henderson and Cockburn, 1996). Survey-based research is also consistently subject to low response rates, which only worsen in the case of emerging countries. In one of the closest comparable studies to ours looking at IINs, for example, Chen (2003) attempted to study international innovation by Chinese firms but received only 28 valid questionnaires out of a total of 279 initially distributed. As a result of these difficulties, most research has focused on selected case studies of R&D investments

carried out by specific multinationals or else specific countries, providing useful albeit hard to generalize evidence (often involving analyses at the macro-level) (Duysters *et al*., 2009; Asakawa and Som, 2008; Tzeng, 2008). Scholars have hence resorted to focusing their analysis at the national level, where patent statistics are widely used (Ma and Lee 2008; Acs, Anselin, and Varga, 2002; Bas and Sierra, 2002; Guellec and van Pottelsberghe de la Potterie, 2001; Grupp and Schmoch, 1999; Bergek and Bruzelius, 2010; Picci, 2010). The reasons why many scholars prefer patent data also include: (1) availability; (2) the considerable potential for investigating cooperative innovation activities (owing to the available information about location of inventions and owners); (3) patents cover fairly extensive time periods, which allow for longitudinal, dynamic analyses.

Among different available sources, USPTO datasets are commonly employed. It is acknowledged these patent registrations represent a large sample of high-quality, official inventions (Grupp and Schmoch, 1999).We therefore also use USPTO grant patents to compare the use of IINs of DMNCs and EMNCs at the national level. In terms of our sample selection, China, India and Brazil are among the most attractive destinations for DMNCs' R&D investments (OECD, 2008; Karabag, Tuncay-Celikel, and Berggren, 2011) as well as the largest outward investors among EMNCs. We also included Russian multinationals and its market, as it is a rapidly growing important emerging market (Gammeltoft, 2008). For DMNCs, we choose the top 18, most inventive countries found within the USPTO data set, namely: Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Portugal, Luxembourg, Norway, Spain, Sweden, the Netherlands, the United States, United Kingdom. We look at BRIC EMNC related activities in DMNCs and vice versa. In doing so, our method provides a control for the impact of psychic distances and the potentially confounding factor of differing liabilities of foreignness. Both DMNCs and

EMNCs alike, in entering each other's markets, face equal psychic distances when establishing IINs within this sample. Further, we run a number of diagnostic checks to ascertain the potential impacts of industrial composition within our sample. If, for example, the EMNC sample contained a larger share of industries predisposed to establishing IINs, then this would create upward biases in our estimation of EMNC' predisposition to generate patents from their IINs. However, we find this not to be the case and actually find upward biases are more likely to occur, if at all, within the DMNC sample.[1]

We focus on a relatively long 20-year observation frame between 1990 and 2009, which coincides with the growth of R&D internationalization of DMNCs in EMNCs (Almeida, 1996; Cantwell, 1999; Archibugi and Michie, 1997) as well as the increasing outward investment of EMNCs to developed markets. This also includes the so called 'third wave' of EMNCs strategic asset and knowledge seeking in developed markets (Gammeltoft, 2008; Deng, 2009). In order to balance out any single-year anomalies, we also aggregated our data over 4-year time periods, to provide a number of cross-sections. Although this choice is somewhat arbitrary, a 4-year period is long enough reduce the impact of anomalous spikes in annual data and facilitates more meaningful analysis. We focus on 5 time spans: 1990-1993, 1994-1997, 1998-2001, 2002-2005, 2006-2009.

3.2 Patents and organizational mechanisms

[1] DMNCs are more heavily concentrated in technology based industries and ones that are more predisposed to develop and engage in IINs. For example, in the EMNE sample 20% of the patents were found in chemicals and pharmaceuticals, compared to a higher 31% in the DMNC sample. Similarly 10% of EMNC patents were in electronics, compared to a higher 31% in the DMNC sample. Engineering patents, by contrast stood at 15% for EMNCs compared to a lower 13% in DMNCs and for general machinery these stood at 55% for EMNCs compared to 44% for DMNCs.

USPTO patent data documents contain standardized data relating to the inventors' stated country of where the inventive activities took place as well as the assignees' stated address in the country where the owners are located. The information on the location of inventor and owner has been widely used to trace international innovation activities in extant literature (Ma and Lee, 2008; Picci, 2010; Guellec and van Pottelsberghe de la Potterie, 2001). This study furthers this line of inquiry by linking this important information to EMNCs and DMNCs' IIN organizational mechanisms. Our method, which we now elaborate upon, assigns patents to a 3×3 matrix according to the address information of inventors and owners (see Table 1)[2].

Insert Table 1 here

In the *inventor* dimension, a patent can be invented by relying on domestic inventors, domestic and foreign inventors, or foreign inventors. Similarly, in the *owner* dimension a patent can be owned by domestic organizations/individuals, shared by domestic and foreign organizations/individuals, or owned by foreign organizations/individuals. From this, a nine-cell matrix is obtained. The cases of Domestic inventors with Domestic owners (D-D) and Foreign inventors with Foreign owners (F-F) are, however, excluded, as these represent indigenous innovation efforts and have no international network element. We now explain how we interpret the meanings of the remaining seven cells. For illustrative purposes, we use the example of Chinese EMNCs entering the United States and the converse, DMNCs from the United States entering China. We thus assume the domestic context is China in this example .

[2] There are a small number patents without assignee information which we omitted.

***Case D-DF*:** is a Chinese owner with Chinese and US inventors. In this scenario Chinese MNCs own the patent but it was invented by both Chinese and US inventors. We interpret a *D-DF* case as involving Chinese MNCs combining efforts from their US R&D subsidiaries with their headquarters (or other units) in China. It therefore to some extent reflects the ability of Chinese MNCs to co-ordinate their intra-MNC, internal IINs, where the innovation is a product of the interaction between foreign R&D units and their home headquarters.

***Case D-F*:** is a Chinese owner with US inventors. This represents the patent outputs of the R&D subsidiaries of Chinese MNCs in the US.

The third column of Table 1 is reflective of ownership where a patent was co-assigned. These are associated with independent firms that are cooperating in invention activities, such as joint R&D or in the later stages of invention commercialization which brings complementary knowledge or resource holders together. It thus can be seen as MNCs' cooperative learning by developing non-equity based partnerships in host locations. However, the three cells in this column can all be significantly different.

***Case DF-D*:** is Chinese-US joint ownership with Chinese inventors (DF-D). This scenario might reflect US MNC partnerships and collaboration in China. Chinese and US companies jointly hold the patent which was invented solely by Chinese inventors.

***Case DF-DF*:** Chinese-US joint ownership with Chinese-US joint inventors (DF-DF). In this case, the inventors' stated countries of residence are China and US; similarly, the owners are also from these two countries. This joint effort cannot be separated; it thus might reflect both the efforts of Chinese and US companies in partnering in host countries.

***Case DF-F*:** is Chinese-US joint ownership with sole US inventors (DF-F). Similar to case *DF-D*, this might reflect Chinese MNC cooperation achievements in US with US partners. It indicates the extent of Chinese MNC partnerships in the US.

The fourth column in Table 1 can be interpreted similarly to the second column on Chinese MNCs, though now corresponding to US MNCs (denoted by F here) generating patents via their IINs. By setting up R&D affiliates in China to either tap into China's local pool of talents (F-D), or reap the benefits of the decentralized R&D subsidiary arrangement by the interactions between R&D affiliates in China and their US headquarters (F-DF).

3.3 Organizational mechanism indices for international innovation

As discussed in Section 2, in the dual network approach (Zanfei, 2000; Meyer *et al*., 2011) successfully orchestrating IINs includes externally embedding overseas R&D affiliates to innovate, as well as managing interactions between overseas R&D affiliates and domestic operations. Here we use number of patents in the case of domestic owners with domestic-foreign joint inventors (case D-DF and F-DF) to proxy the interactions between overseas R&D affiliates and domestic operations. The number of patents in the case of a domestic owner with foreign inventor (D-F and F-D) captures the output of overseas R&D affiliates and are therefore also relevant[3]. Given that DMNCs and EMNCs have different innovation capabilities and subsequent disproportions in patent numbers we use the ratio of each kind of patent to total number of patents for each MNC. We summarize our hypotheses, cases and

[3] We also conducted the analyses separately using Case *DF-F* and Case *DF-D* for domestic and foreign MNCs respectively, and additionally using an aggregated measurement including these two and DF-DF for both kinds of MNCs. Our results are similar for the BRIC sample aggregated.

various corresponding indicators to test these hypotheses in Table 2. To test hypotheses 1 and 2, we use standard deviation and cosine similarity formulas to develop two relevant indices, namely, the convergence and volatility index. Our indices of convergence and volatility are derived as follows:

$$\text{The convergence index}=\frac{\sum_{i=1}^{n} E_i \times D_i}{\sqrt{\sum_{i=1}^{n} (E_i)^2} \times \sqrt{\sum_{i=1}^{n} (D_i)^2}}$$

Where E and D mean the two vectors for EMNCs and DMNCs respectively, n=3. Cosine similarity is a measure of similarity between two vectors by measuring the cosine of the angle between them. The cosine of the angle between two vectors thus determines whether two vectors are pointing in roughly the same direction. In the following analysis a high value indicates convergence between EMNCs and DMNCs'.

$$\text{The volatility index}=\sqrt{\frac{\sum(X-\overline{X})}{(n-1)}}$$

Where X means each ratio of patent corresponding to different organizational mechanisms, $\overline{X}$ is the mean of X, n is the number mechanisms, n=3. The standard deviation shows how much variation exists from the mean. A high standard deviation indicates high volatility of an MNC's IIN organizational portfolio.

Insert Table 2 here

3.4. Data description and limitations

It should be noted that the patents from our BRIC sample accounted for 73.20% of all emerging market patents in 2009 and those of the 18 developed countries 88.4% of all developed market patents. According to the USPTO data, therefore, we can conclude our sample is quite comprehensive and may be fairly representative of the broader population of EMNCs and DMNCs. For the BRIC country grouping, 95% of the patents were owned by corporations. For the developed country group 88.61% were owned by corporations. Thus businesses with a multinational dimension are clearly important players in our sample data.

Looking specifically within the EMNC sample, both China and India have been more active in developing their IINs and their resulting patenting activity has been considerably greater than that of Russia and Brazil. Throughout the sample period the China and India related IIN patent count, for example, stood at above 95% of all BRIC patents in the D-F and D-DF categories (categories we focus on). Thus of the 1,720 patents filed in these categories between 2006 and 2009 less than 50 were filed by Russian and Brazilian MNCs. Most of these types of patents, moreover, were filed after 2001. In this period before 2001 India was also a more important generator of IIN related patents than China, which subsequently has grown quickly. India generally held over 80% of all such patents before 2001, indicating the activity of the other three countries was limited. After 2001, however, China's share rose rapidly (as did the overall number of IIN related patents produced in the BRICs) to share roughly equal amounts with India. Indeed, 54% of all BRIC IIN related patents presented in Table 3 were produced in the 2002-2009 period, and 72% in the 1998-2009 period. The aggregated supranational sample therefore conceals a degree of regional and temporal

variation, with most of the patents generally created in later time periods and predominately by Chinese and Indian MNCs.

Insert Table 3 here

As noted, in order to balance out any single-year anomalies, a four-year accumulated patent number was used. Nevertheless, even using this procedure we are still subject to anomalies among the four BRIC countries; for instance, Russia and Brazil had only one patent case each from the DF-DF category during 2006 to 2009. In total, Russia only had 38 patents in the cases *D-DF* and *D-F* and similarly Brazil only had 66 within the entire 20 year period. As such we present our analysis at both the national level, so as to provide individual country-level trends, as well as at an aggregated supranational level (i.e. for the purposes of describing overall trends based on the entire EMNC sample, which generally follow those found at the level of individual countries).

4. Results

Table 3 shows that during 1990 to 2009 there were imbalanced patent flows between the BRIC countries and 18 developed countries. DMNCs successfully applied for 37,214 patents which came from efforts (or combined efforts) in their BRIC R&D subsidiaries (*F-D*, 15,918, *F-DF*, 21,296). For EMNCs total DMNC subsidiary patents reached 5,235 (*D-F*, 4,555 and *D- DF*, 680). During this period there were 1,968 patents co-owned and shared by DMNCs and EMNCs (*DF-D*, *DF-DF*, *DF-F*). Furthermore, 85% of the co-ownership patents involved

both inventors from BRIC and developed countries (DF-DF). EMNCs mainly employed overseas R&D affiliates for successful patent generation in their IINs, with a high growth in the dimension of the interaction domain (D-DF). Cooperation with foreign partners, however, accounted for a relatively small share of their patents compared with direct reliance on foreign subsidiaries (i.e. D-F, 4,555 total) (Table 3). Patent growth has rapidly increased from 1990 to 2009 in our sample. The growth, however, is uneven among different kinds of patents and thus associated organizational mechanism volatility may possibly be predicted.

We report the convergence index in Table 4. In Hypothesis 1 we predicted that EMNCs could address unfavorable CSAs and simultaneously develop FSAs in learning how to better organize and manage successful IINs. Our results show that there is a consistent upward trend in this convergence index (Fig. 3). Again, this is confirmed at the level of all individual BRIC countries as well as at the supranational level as the value of the convergence index in the first column in Table 4 increases over time. At the supranational level it retains a relatively consistent upward trend over time for this value (also shown in Fig 3). At the national level, Brazilian MNCs demonstrated a somewhat inconsistent trend though between 1990 and 2009 though this still remained upwards, implying convergence. At the national level Chinese MNCs seem to have learnt most rapidly and this trend is particularly evident for recent years. The convergence value jumped from 0.245 during period 2002-2005 to 0.413. Indian MNCs have exhibited a gradual path towards convergence (Table 4).

Insert Table 4 here

The volatility index for EMNCs and DMNCs is reported in table 5 (and Figures 1 and 2). A noticeable difference between EMNCs and DMNCs is that the former consistently, with the exception of Russia in several years, have higher levels of IIN volatility compared with DMNCs over the periods in question. Their volatility index, however, is generally decreasing over time (see Fig. 1) (supporting *hypothesis 2*). In the case of the aggregated BRIC levels, the first column represents the EMNCs' volatility and its evolution over time. Similarly, the second column presents the DMNC' volatility. In each period, the value of EMNC volatility is larger than DMNC volatility, which also provides support for hypothesis 2 at the supranational level. On average, the volatility for EMNCs is 0.288, while for DMNCs is 0.247. Within the four BRIC countries, Chinese MNCs experienced the greatest IIN volatility. Their average volatility indices are much higher than those of their DMNC counterparts with the exception of Russia, where the average volatility for DMNCs is higher. A graphical representation of the evolution in volatility index is shown for each BRIC country in Fig. 2.

Insert Table 5 here

Insert Fig.1, 2 here

Insert Fig.3 here

Insert Fig.4, here

---

5. Discussion

5.1 Convergence in the IINs used by EMNCs and DMNCs

Within the current research on the international expansion of EMNCs few studies: (i) empirically compare the innovation strategies of EMNCs with DMNCs, despite this being a key issue in the conceptual literature; (ii) measure and compare the actual end outputs of R&D related international networks of innovation related technological investments; (iii) explore the underlying IINs used to achieve these goals. These lacunae exist despite the fact that at the very heart of the current conceptual debate on EMNCs is the question of whether and how they are different to DMNCs. The hypotheses we have tested using our comparative models cast some further light on these questions.

Firstly, our results suggest that EMNCs have not been entirely unsuccessful in orchestrating their IINs, in so far as, despite their acknowledged comparative lack of FSAs and unfavorable

CSAs, the ratio of patents they produce via their IINs to their total patenting activity, over the longer term, is converging with that of DMNCs (in emerging markets). It is, moreover, converging in two senses: in the *volatility* of the IIN mechanisms used, as well as the relative number of patents produced from such IINs. This finding stands in contrast to a strand of thought within the IB literature that has argued that EMNCs, lacking ownership advantages (relying only on CSAs), might struggle to benefit from development of IINs (Rugman, 2009).

What other conceptual models are these findings consistent with? One more positive interpretation of our results is that EMNCs do possess certain ownership advantages, along the lines described earlier (Narula, 2012; Cuervo-Cazurra, 2012; Ramamurti, 2012). This enables them, for example, to successfully address the dual network problem, as they have gradually learned to overcome the challenges of multiple embeddednes, including reverse knowledge transfer. Narula (2012) has argued that a prerequisite of successful FDI, contrary to the arguments of the 'springboard' (Luo and Tung, 2007) and 'LLL' (link, leverage, learn) perspectives (Matthews, 2006), is that EMNCs do 'have existing O assets they wish to augment' (Narula, 2012: 195). The idea EMNCs possess certain FSAs, including a certain level of absorptive capacity, is now being more readily entertained (Ramamurti *et al*., 2013). Moreover, as EMNCs internationalize, they will mitigate some of the negative domestic market CSAs they face, while still leveraging the more facilitating CSAs available to them. Over time, as their domestic market CSAs also improve, and exposure to negative domestic CSAs is reduced (via institutional arbitrage/exit, as discussed earlier in hypothesis 2), reduced IIN volatility would be expected. This argument or view of EMNC' IIN expansion is also consistent with our findings on IIN volatility (hypothesis 2). This evolutionary perspective, involving the simultaneous evolution of both firm-specific and country-specific elements, is certainly one possible interpretation of our findings. As Narula (2011) explains it,

orchestrating successful IINs is not straightforward and is only achieved after a lengthy learning process. MNE subsidiaries must 'be embedded within the local milieu as well as deeply integrated within the MNE network', and this is a challenge for 'even the most experienced MNEs' (Narula, 2012: 195). It therefore takes time.

Hennart's (2012) bundling model is another conceptual framework that our findings are consistent with. This model again focuses on the differences between home CSAs faced by DMNCs and EMNCs, following the currently popular line of thinking that their unique features stem from 'the country of origin', which in turn 'affects their global strategy' (Cuervo-Cazurra, 2012; 163). Hennart's (2012) model is highly relevant, as it specifically discusses how domestic CSAs may impact on technology acquisition in EMNCs. EMNCs, it argues, have preferential access to domestic complementary local resources in their home markets. This protects them from competition from DMNCs and allows them to earn super-normal profits, underwriting their more speculative investments in IINs. There are strong incentives for EMNCs to acquire foreign technologies via the development of their innovation networks in developed markets in this model. This is because their preferential access to local markets allows them to use such technologies within their domestic market and appropriate what are akin to domestic market monopoly rents. Our results, following the predictions of this model, do suggest extensive reverse technology flows from developed to emerging markets, involving domestic EMNCs strongly interacting with their foreign subsidiaries. What is most striking is that in terms of absolute numbers patents generated by foreign subsidiaries of EMNCs (i.e. D-F), by far the largest most popular single INN mechanism involves the D-F case. It is also the category (excluding all partnerships, which must be treated with care owing to the limited sample size), where the nominal distance between

DMNCs and EMNCs is lowest (15,918 in DMNCs compared to 4,555 in EMNCs). These results are consistent with Hennart's (2012), bundling model, which strongly predicts the D-F case as a likely mechanism for technology transfer from developed markets to EMNCs in their domestic markets.

These interpretations of our findings, of course, are based on analysis of individual BRIC national level data and the aggregated supranational, where the overall trends towards both convergence and of reduced volatility are noted. At the national level we did observe in places a wider range of experience in the trends from year to year, perhaps in part driven by the smaller volumes of patents being recorded by Russian and Brazilian MNCs. Nonetheless, similar general patterns seemed to hold when looking over the period as a whole. It is noteworthy, moreover, that China was identified as experiencing most rapid convergence with DMNCs (Table 4) in our analysis, as well as much reduced overall volatility in IINs (Table 5). This seems consistent with the findings of some other current research, which has highlighted the rapid and dynamic expansion of Chinese MNCs' outward expansion with a view to developing their capabilities for innovation (Child and Rodrigues, 2005; Deng, 2009), favorable country-level factors facilitating such FDI, as well as firm-level FSAs that may lead to successful outcomes (Ramamurti *et al.*, 2013). Further research may look to further explain the specific individual national level convergence and volatility patterns outlined here.

6. Conclusion

Are emerging-country EMNCs different to developed-country multinationals (DMNCs) and do we need new theoretical models, therefore, to explain their strategic innovation behaviors? This central question, much talked of in the International Business literature, is also closely related to the idea that EMNCs undertake investments in developed markets for the purposes of developing their comparatively weaker firm specific intangible assets, particularly their innovative capabilities. Within the burgeoning literature on EMNCs, however, few studies have yet directly and systematically observed the *outcomes* of EMNC international innovation networks or directly *compared* them with those of DMNCs. Furthermore, the types of IIN used in such processes remain understudied. Here we have made a start in what we believe is likely to be a growing area of research. Our comparative analysis of the IINs of EMNCs draws from patent data from the BRICs and 18 developed countries spanning 20 years. Our findings are broadly supportive of some current conceptual models of EMNCs which focus on the unique and idiosyncratic nature of EMNC domestic CSAs (Narula, 2012; Cuervo-Cazurra, 2012; Hennart, 2012), as well as the gradual learning processes required to develop the requisite FSAs to manage the complex challenge of multiple-embeddedness in different contexts (Meyer *et al*. 2011; Figueireido, 2011). These models appear of particular relevance as they are consistent with our findings regarding both convergence and volatility in the IINs of EMNCs when compared to those of DMNCs.

From a methodological viewpoint, we acknowledge the limitations in our study. International innovation cooperation between developing countries, for example, is also an important part of the international innovation activities of EMNCs (von Zedtwitz, 2005) and our study excludes these cases, despite otherwise capturing a significant share of international innovation activity. We also assume all USPTO patents associated with emerging countries

are owned exclusively by MNCs. This could be problematic owing to some international collaboration between public institutions, such as universities. We also found that our sample had comparatively few observations from some emerging markets (i.e. Russia and Brazil). Despite these limitations, our 3×3 matrix analysis framework and the link to IINs enriches the study of international innovation measurement as well as providing a series of potential new research avenues. Research to date often uses patent data to describe trends in international innovation, without further explanation of the IIN organizational mechanisms underpinning the increasing number of co-inventor and co-ownership patents. Our work pushes this research agenda forward by linking this information to different underlying IINs and their corresponding organizational mechanisms. There are potentially many new research themes that can be explored using this 3×3 matrix approach, such as examining in greater detail the patterns that different firms, countries, and industries use to internationalize their innovation activities, and how these different strategies when combined determine performance.

References

Acs, Z. J., L. Anselin and A. Varga. (2002)Patents and innovation counts as measures of regional production of new knowledge, *Research Policy* , 31 (7), pp.1069-1085.

Almeida, P. (1996)Knowledge sourcing by foreign multinationals: Patent citation analysis in the US semiconductor industry, *Strategic Management Journal* , (17), pp. 155-165.

Ambos, T. C., B. Ambos and B. B. Schlegelmilch. (2006)Learning from foreign subsidiaries: An empirical investigation of headquarters' benefits from reverse knowledge transfers, *International Business Review* ,15 (3), pp. 294-312.

Archibugi, D. and J. Michie. (1997)Technological globalisation: The end of the nation state? (New York: Cambridge University Press).

Asakawa, K. and A. Som. (2008)Internationalization of R&D in China and India: Conventional wisdom versus reality, *Asia Pacific Journal of Management* , 25 (3), pp. 375-394.

Barnard, H. and J. Cantwell. (2007)The internationalization of R&D and the internationalization of innovation, *Research Policy*, 36 (8), pp.1289-1291.

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

Bergek, A. and M. Bruzelius. (2010)Are patents with multiple inventors from different countries a good indicator of international R&D collaboration? The case of ABB, *Research Policy*, 39 (10).

Boisot, M. and Meyer, M.W. (2008), Which way through the open door? Reflections on the internationalization of Chinese firms,*Management and Organization Review*, 4, 349-365.

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

Cantwell, J. (1999)From the early internationalization of corporate technology to global technology sourcing, *Transnational Corporations* ,8 (2), pp. 81-92.

Chen, J. (2003)*Global innovation*(Beijing: Economic Science Press).

Chen, J., and L. Tong. (2003) R&D internationalization and the reformation of Chinese S&T system. Hangzhou(China: Zhejiang University).

Child, J. and Rodrigues, S.B. (2005), The Internationalization of Chinese Firms: A Case for Theoretical Extension?, Management and Organization Review, 1, 381-410.

Cuervo-Cazurra, A. (2012). Extending theory by analyzing developing country multinational companies: Solving the Goldilocks debate. *Global Strategy Journal* 2(3): 153–167.

Deng, P. (2009)Why do Chinese firms tend to acquire strategic assets in international expansion? *Journal of World Business* ,44 (1), pp. 74-84.

Dunning, J. H. and S. M. Lundan. (1998)The geographical sources of competitiveness of multinational enterprises: an econometric analysis, *International Business Review* ,7 (2), pp. 115-133.

Dunning, J. H. and S. M. Lundan. (2009)The Internationalization of Corporate R&D: A Review of the Evidence and Some Policy Implications for Home Countries, *Review of Policy Research* ,26 (1/2), pp.13-33.

Duysters, G., J. Jacob, C. Lemmens and J. Yu. (2009)Internationalization and technological catching up of emerging multinationals: a comparative case study of China's Haier group, *Industrial and Corporate Change* , 18 (2), pp. 325-349.

Figueiredo, P.N. (2011), The role of dual embeddedness in the innovative performance of MNE subsidiaries: evidence from Brazil, *Journal of Management Studies*, 48, 417-440.

Florida, R(1997)The globalization of R&D: Results of a survey of foreign-affiliated R&D laboratories in the USA, *Research Policy* ,26 (1), pp.85-103.

Gammeltoft, P. (2008)Emerging multinationals: Outward FDI from the BRICS countries, *International Journal of Technology and Globalisation* ,4 (1), pp. 5-22.

Ghoshal, S. and C. A. Bartlett. (1988)Creation, adoption,and diffusion of innovations by subsidiaries of multinational corporations, *Journal of International Business Studies* ,19 (3), pp. 365-388.

Gilsing, V., B. Nooteboom, W. Vanhaverbeke, G. Duysters and A. van den Oord. (2008)Network embeddedness and the exploration of novel technologies:Technological distance, betweenness centrality and density, *Research Policy* ,37 (10), pp.1717-1731.

Griliches. Z. (1998) *R&D and productivity*(Chicago: The University of Chicago Press).

Grupp, H. and U. Schmoch. (1999)Patent statistics in the age of globalisation: New legal procedures, new analytical methods, new economic interpretation, *Research Policy* ,28 (4), pp.377-396.

Guellec, D. and B. van Pottelsberghe de la Potterie. (2001)The internationalisation of technology analysed with patent data, *Research Policy* ,30 (8), pp.1253-1266.

Hagedoorn, J.(1993)Understanding the rationale of strategic technology partnering: Inter-organizational modes of cooperation and sectoral differences, *Strategic Management Journal* , (14), pp.371-385.

Henderson, R. and I. Cockburn. (1996)Scale, scope, and spillovers: The determinants of research productivity in drug discovery, *RAND Journal of Economics*, 27 (1), pp.32-59.

Hennart, J.-F. 2012. Emerging market multinationals and the theory of the multinational enterprise. *Global Strategy Journal* 2(3):168–187.

Hitt, M. A., H. Li and W. J. Worthington. (2005)Emerging markets as learning laboratories: Learning behaviors of local firms and foreign entrants in different institutional contexts, *Management and Organization Review* , 1 (3), pp.353-380.

Karabag, S. F., A. Tuncay-Celikel and C. Berggren. (2011)The limits of R&D internationalization and the importance of local initiatives: Turkey as a critical case, *World Development*,39 (8), pp.1347-1357.

Khanna, T. and Yafeh, Y. (2007), Business groups in emerging markets: Paragons or parasites?, *Journal of Economic Literature*, 331-372.

Kogut, B., and U. Zander. (2003)Knowledge of the firm and the evolutionary theory of the multinational corporation, *Journal of International Business Studies* ,34 (6), pp.516-529.

Lahiri, S., Kedia, B.L. and Mukherjee, D. (2012), The impact of management capability on the resource–performance linkage: Examining Indian outsourcing providers, *Journal of World Business*, 47, 145-155.

Lewin, A. and Witt, M. (2007)Outward Foreign Direct Investment as Escape Response to Home Country, *Institutional Constraints Journal of International Business Studies*, 38(4), pp.579-94.

Luo, Y., and Tung, R. L. 2007. International expansion of emerging market enterprises: A spring board perspective. *Journal of International Business Studies* 38(4): 481–498

Ma, Z. and Y. Lee. (2008)Patent application and technological collaboration in inventive activities: 1980-2005,*Technovation* ,28 (6), pp.379-390.

Madhok , A., and Keyhani , M.2012. Acquisitions as entrepreneurship: asymmetries, opportunities, and the internalization of multinationals.*Global Strategy Journal* 40:26–40.

Matthews, J. A. 2006. Dragon multinationals: New players in 21st century globalization. *Asia Pacific Journal of Management* 23(5): 5-27.

Meyer, K.E., Mudambi, R., and Narula, R. 2011. Multinational Enterprises and Local Contexts: The Opportunities and Challenges of Multiple-Embeddedness. *Journal of Management Studies,* 235-252

Morck, R., Yeung, B. and Zhao, M. (2008), Perspectives on China's outward foreign direct investment, *Journal of International Business Studies*, 39, 337-350.

Narula, R. and J. Hagedoorn. (1999)Innovating through strategic alliances: Moving towards international partnerships and contractual agreements, *Technovation* ,19 (5),pp.283-294.

Narula, R. and A. Zanfei. (2005) Globalisation of Innovation: The role of multinational enterprises, In : F. Jan, M. David and R. R.Nelson (Eds), Handbook of innovation(Oxford : Oxford University Press).

Narula, R. 2012. Do we need different frameworks to explain infant MNEs from developing countries? *Global Strategy Journal* 2(3):188–204.

Nonaka, I. (2007) The Knowledge-Creating Company, *Harvard Business Review* ,85 (7/8), pp.162-171.

OECD. (2008)Globalization and Open Innovation. Paris: OECD, Original edition, OECD: Paris.

Picci, Lucio. (2010)The internationalization of inventive activity: A gravity model using patent data, *Research Policy* , 39 (8), pp.1070-1081.

Ramamurti,R.2012. Commentaries what is really different about emerging market multinationals?*Global Strategy Journal* 2(3): 41–47.

Reddy, P. (1997)New trends in globalization of corporate R&D and implications for innovation capability in host countries: A survey from India, *World Development* ,25 (11), pp.1821-1837.

Rugman, A. 2009. Theoretical aspects of MNEs from emerging countries. In *Ramamurti, R., & Singh, J. (Eds.), Emerging Multinationals in Emerging Markets*: 42-63. Cambridge, U.K: Cambridge University Press.

Rugman A, Verbeke A. 1990. Global Corporate Strategy and Trade Policy. Routledge: London, U.K.Dunning J. 1988. The theory of international production. *The International Trade Journal* 3(1): 21–66.

Tsai, F.-S., L. H. Y. Hsieh, S.-C. Fang and J. L. Lin. (2009)The co-evolution of business incubation and national innovation systems in Taiwan, *Technological Forecasting and Social Change* , 76(5), pp. 629-643.

Tzeng, C-H. (2008)Developing high-technology latecomer firms to compete internationally: A three-sector growth model, *Journal of International Management* , 14 (2), pp.190-206.

UNCTAD. (2005)Globalization of R&D and developing countries (United Nations, Geneva and New York: Proceedings of the Expert Meeting).

UNCTAD. (2013)*World Investment Report 2013*: Global Value Chains: Investment and Trade for Development, (United Nations, Geneva and New York: Proceedings of the Expert Meeting).

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

Von Zedtwitz, M. (2005)International R&D Strategies in Companies from Developing Countries – the Case of China(New York: UNCTAD).

Wang, C., and M. I. Kafouros, (2009)What factors determine innovation performance in emerging economies? Evidence from China, *International Business Review* ,18, pp.606-616.

Williamson, P.J., Ramamurti, R. and Fleury, A. and Fleury,,M. T. L. (2013)The Competitive Advantage of Emerging Market Multinationals(Cambridge University Press: Cambridge).

WIR. (2005)World investment report: Transnational coporations and the internationalization of R&D(New York and Geneva: United Nation).

Witt, M.A. and Lewin, A.Y. (2007), Outward foreign direct investment as escape response to home country institutional constraints, *Journal of International Business Studies*, 38, 579-594.

Zanfei, A. (2000)Transnational firms and the changing organization of innovative activities, *Cambridge Journal of Economics* , 24, pp.515-542.

Zhang, J., and C. Baden-Fuller. (2010)The influence of technological knowledge base and organizational structure on technology collaboration, *Journal of Management Studies*, 47 (4), pp.679-704.

Table 1. Analyses matrix of patent and organizational mechanism of international innovation

Owner **Inventor**	Domestic	Domestic-Foreign joint ownership	Foreign
Domestic	D-D	DF-D	F-D
Domestic-Foreign joint inventor	D-DF	DF-DF	F-FD
Foreign	D-F	DF-F	F-F

Table 2. Hypotheses, cases and corresponding indicators

hypotheses	Cases (standing at the Emerging side)	Proposed indicators
EMNCs' IINs and their outputs will converge with DMNCs over time (Hypothesis 1)	Cases D-DF, D-F, DF-DF, DF-F, for EMNCs Cases F-D, F-DF, DF-DF, DF-D for DMNCs	Convergence index increases over time
EMNCs' IINs and their outputs will be more volatile than DMNCs' (Hypothesis 2)	Cases D-DF, D-F, DF-DF, DF-F, for EMNCs Cases F-D, F-DF, DF-DF, DF-D for DMNCs	Volatility index of EMNCs > Volatility index of DMNCs

Table 3. Aggregated data for both EMNCs and DMNCs at the level of BRICs

Year	Case D-DF	Case D-F	Case DF-D	Case DF-DF	Case DF-F	Case F-D	Case F-DF
1990-1993	18	643	4	249	26	1568	1530
1994-1997	118	667	22	360	27	1977	1858
1998-2001	101	878	18	364	36	3310	3321
2002-2005	131	959	21	352	26	3893	5531
2006-2009	312	1408	87	344	32	5170	9056
Total	680	4555	152	1669	147	15918	21296
Growth	37.78	7.08	38.00	6.70	5.65	10.15	13.92

Source: USPTO (1990-2009)

Table 4. Convergence index

	BRIC	Brazil	Russia	India	China
1990-1993	0.273	0.371	0.222	0.269	0.206
1994-1997	0.305	0.421	0.376	0.304	0.327
1998-2001	0.319	0.439	0.138	0.291	0.273
2002-2005	0.325	0.354	0.148	0.303	0.245
2006-2009	0.335	0.365	0.388	0.339	0.413
Average	0.311	0.390	0.254	0.301	0.293

Table 5. Volatility index

	BRIC		Brazil		Russia		India		China	
Period	EMNCs	DMNCs	EMNCS	DMNCS	EMNCs	DMNCs	EMNCs	DMNCs	EMNCs	DMNCs
1990-1993	0.336	0.223	0.382	0.341	0.289	0.000	0.334	0.219	0.542	0.282
1994-1997	0.234	0.211	0.278	0.288	0.265	0.360	0.230	0.197	0.469	0.287
1998-2001	0.284	0.242	0.294	0.284	0.351	0.343	0.268	0.230	0.537	0.285
2002-2005	0.290	0.269	0.256	0.267	0.309	0.292	0.226	0.269	0.511	0.293
2006-2009	0.295	0.292	0.315	0.286	0.128	0.282	0.319	0.326	0.287	0.280
Average	0.288	0.247	0.305	0.293	0.269	0.320	0.276	0.248	0.469	0.285

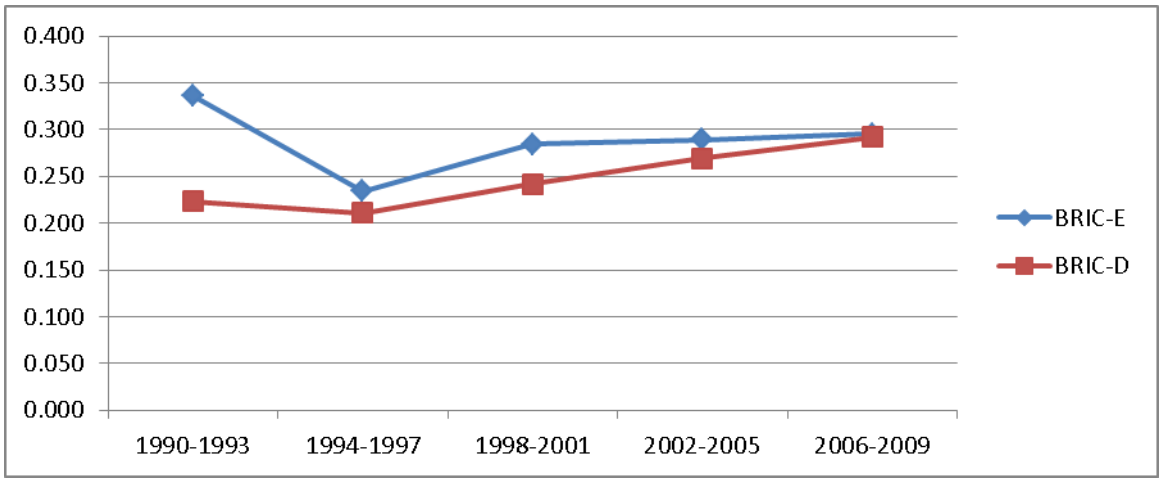

Fig. 1 Changes in volatility index at BRIC aggregated level

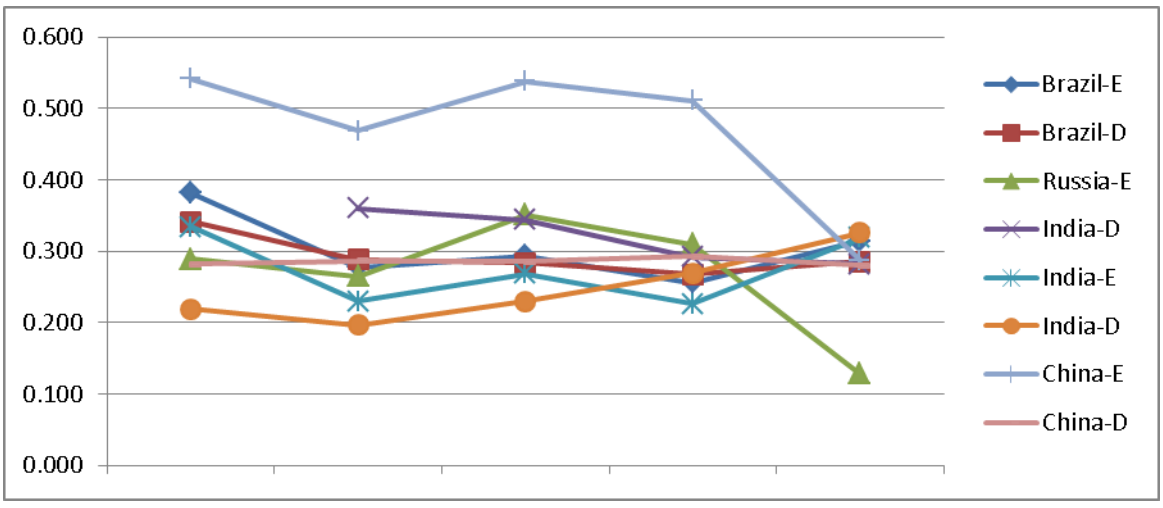

Fig. 2 Changes in volatility index in BRIC individual countries

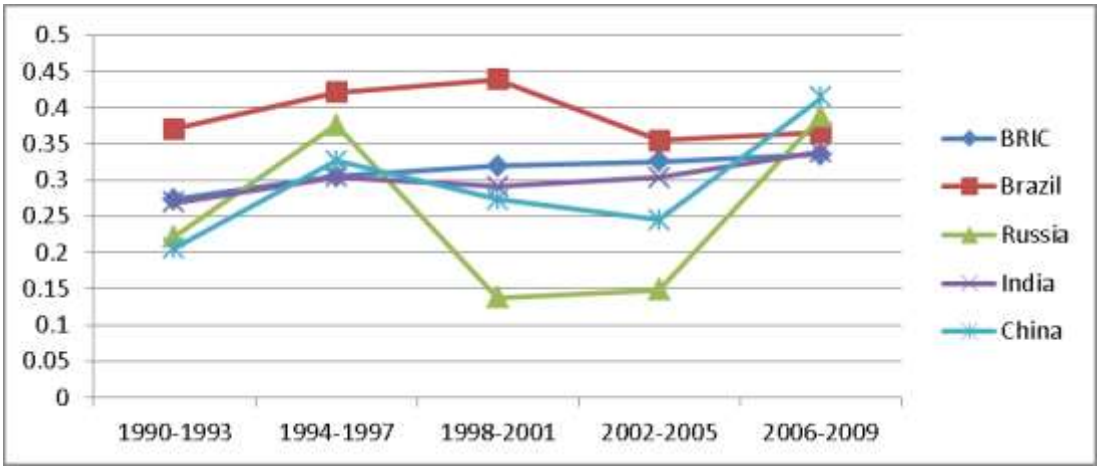

Fig. 3 Changes in convergence index in BRIC individual countries

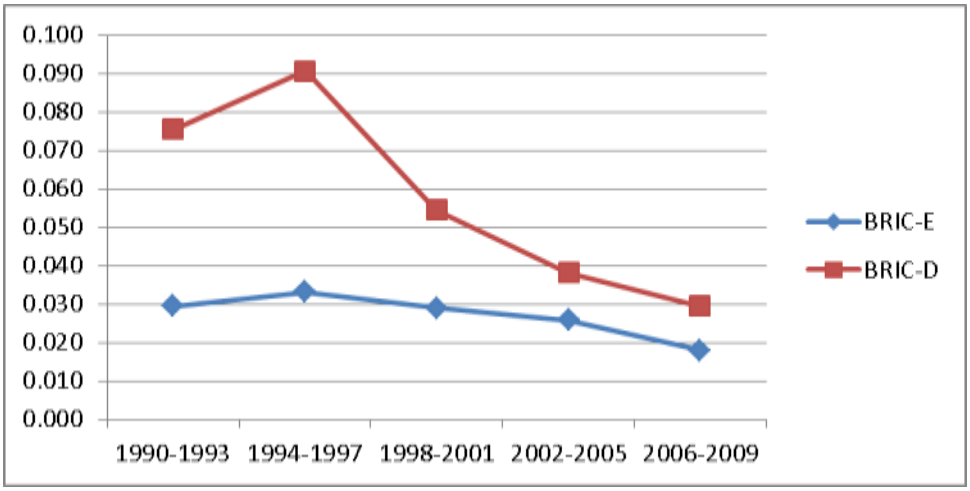

Fig. 4 Changes in volatility index at BRIC aggregated level (BRIC-E*10)