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Catch-up in technological capability: a comparison between Korea and Brazil

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Abstract

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The literature on catch-up processes in emerging economies (e.g., Abramovitz, 1986) describes the process in which emerging economy firms derive parity in technological capabilities with firms from advanced economies by proactively investing in upgrading their capabilities. The key idea behind the catch-up process is that the greater the technological gap existing between a leading country and a following country, the more potential there is for a following country to grow rapidly (Abramovitz, 1986).

The evidence on the actual process of catch-up across emerging countries seems to agree on the importance of acquiring technologies from advanced economies and building. Thereafter, the evidence seems to indicate multiple paths, with some pointing to the importance of building relationships with advanced economy firms to develop absorptive capacity (Kumaraswamy, Mudambi, Saranga, & Tripathy, 2012), while others suggest the importance of developing capabilities in-house through learning-by-doing (Park & Lee, 2006). There is some empirical evidence that firms from emerging economies have yet to catch-up on innovation capability (Awate, Larsen, & Mudambi, 2012); however, through a deliberate and consistent technological effort, firms in emerging economies might be able to go beyond production capability. The skills involved in optimizing the operation of established plants, may achieve innovation capabilities, skills

and technologies necessary to create new products or services (Amsden, 1989).
A broad knowledge base is crucial for innovation (Bierly and Chakrabarti, 1996). Firms with innovation capabilities thus create and leverage knowledge over a wide range of disciplines by tapping into a diverse set of knowledge in foreign locations. This enables the firm to be in a better position to combine knowledge in a more complicated way (Bierly & Chakrabarti, 1996), thereby creating causal ambiguity which increases the sustainability of competitive advantages (Reed & DeFillippi, 1990). For instance, owing to the accumulation of knowledge stores and recombinative capabilities (Kogut & Zander, 1992), MNEs from advanced economies conduct more foreign R&D to tap into a diverse set of external knowledge abroad to improve their competitive position (Berry, 2006). Since inventors from MNEs from advanced economies may have more access to pipelines and personal relationships (Lorenzen & Mudambi, 2013), they would have greater potential to engage in international collaboration. Geographically dispersed inventor networks may increase the chance of recognizing knowledge recombination opportunities by allowing collaboration with inventors with different knowledge, which in turn influences on catch-up ability of firms in emerging economies.
In this study, we compare catch-up in technological capability in case of Korea and Brazil in the context of pharmaceutical industry by looking at dispersion of inventor networks. Korea and Brazil represent the exemplary cases of disparity in catch-up among late industrializing countries (Moreira, 1995). Our data is based on patents granted by the U.S. Patent and Trademark Office (USPTO) during the period 1980 ? 2010, with inventors and/or assignees based in Korea and Brazil, respectively. Our early finding indicates that Korea shows a greater number of patents granted in the US than Brazil. Upon examining the dispersion of inventor networks between the two economies, those belonging to domestic firms show relatively low inventor diversity relative to those of foreign MNEs. Although these results show a similar pattern, we suspect the underlying forces may be quite different. We suspect that in case of Korea, low inventor dispersion of domestic firms may be attributed to the more centralized R&D of Korean firms and/or the accumulated internal technological capability within the firms. In case of Brazil, it might be due to the significant lack of internal technological capability of local firms. During catch-up process, government policy plays a crucial role on the pattern of catching-up, and eventually the chance for successful catching-up; outward-oriented Korean government puts greater emphasis on strong commitment to education as well as science and technology (Moreira, 1995), thus laying the foundation for Korean firms to build and upgrade their competencies by conducting internal R&D essential for innovation. However, inward-oriented Brazilian government produced a weak local private sector and a poorly qualified workforce (Moreira, 1995). Such a different orientation of governments toward their economies inevitably results in very different types of technological effort such that Korean firms rely more on internal capability building, whereas, Brazilian firms heavily rely on FDI which might be beneficial just for production capability.

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Abstract

A substantial body of literature on upgrading and catch-up processes in emerging economies investigate the actual process of catch-up across different emerging market countries, however, little attention has been paid to how catch-up at the national level is translated into firms' and individuals' inventive activities and consequent outcomes. Therefore, in this study, we address the gap in the catch-up literature by comparing the catch-up in of technological capabilities in case of Korea and Brazil in the context of pharmaceutical industry by looking at the dispersion and density of inventor networks. Our early finding shows that in two countries, those belonging to domestic firms show relatively low inventor diversity relative to those of foreign MNEs. Although these results show a similar pattern, we suspect the underlying forces may be quite different.

INTRODUCTION

Economic activity in emerging markets is increasingly dynamic with market liberalization and privatization forces at play. In the face of economic liberalization and privatization, thus, domestic firms in emerging markets are left to adapt to a turbulent environment (Suarez & Oliva, 2005) in which foreign MNEs continue to enter (McDermott & Corredoira, 2010) by continuously improving their products and processes, and shifting from lower to higher-value-added economic activities (Giuliani, Pietrobelli, & Rabellotti, 2005).

The literature on upgrading and catch-up processes in emerging economies (e.g., Abramovitz, 1986; Amsden, 1989) describes the process in which firms from emerging economy markets derive parity in technological capabilities with firms from advanced economies by proactively investing in upgrading their capabilities. The key idea behind the catch-up process is that the greater the technological gap existing between a leading country and a following country, the more potential there is for a following country to grow rapidly (Abramovitz, 1986).

The evidence on the actual process of catch-up across different emerging market countries seems to agree on the importance of acquiring technologies from advanced economies and building. Thereafter, the evidence seems to indicate multiple paths, with some pointing to the importance of building relationships with advanced economy firms to develop adsorptive capacity (Kumaraswamy, Mudambi, Saranga, & Tripathy, 2012), while others suggest the importance of developing capabilities in-house through learning-by-doing (Park & Lee, 2006). There is some emprical evidence that firms from emerging economies have yet to catch-up on innovation capability (Awate, Larsen, & Mudambi, 2012); however, through a deliberate and consistent technological effort, firms in emerging economies might be able to go beyond

production capability. The skills involved in optimizing the operation of established plants, may achieve innovation capabilities, skills and technologies necessary to create new products or services (Amsden, 1989).

It has been suggested that a broad knowledge base is crucial for innovation (Bierly and Chakrabarti, 1996). Firms with innovation capabilities thus create and leverage knowledge over a wide range of disciplines by tapping into a diverse set of knowledge in foregin locations. This enables the firm to be in a better position to combine knowledge in a more complicated way (Bierly & Chakrabarti, 1996), thereby creating causal ambiguity which increases the sustainability of competitive advantages (Reed & DeFillippi, 1990). For instance, owing to the accumulation of knowledge stores and recombinative capabilities (Kogut & Zander, 1992), MNEs from advanced economies conduct more foreign R&D to tap into a diverse set of external knowledge abroad to improve their competitive position (Berry, 2006). Since inventors from MNEs from advanced economies may have more access to pipelines and personal relationships (Lorenzen & Mudambi, 2013), they would have greater potential to engage in international collaboration. Geographically dispersed inventor networks may increase the chance of recognizing knowledge recombination opportunities by allowing collaboration with inventors with different knowledge and perspectives, which in turn influences on catch-up ability of firms in emerging economies.

Even though a substantial body of literature on upgrading and catch-up processes in emerging economies investigate the actual process of catch-up across different emerging market countries, little attention has been paid to the level of the economic actor-i.e., the firm or institution level. Rather much attention has been paid to the national level. For instance, Amsden

(1989) investigates how government policy influence on the competitiveness of Korean industries through affecting factor markets. Similarily, Park and Lee (2006) contrast Korea and Taiwan by linking the technological regime to the technological catch-up process. However, how catch-up at the national level is translated into firms' and individuals' inventive activities and consequent outcomes is less explored. Furthremore, the literature on catch-up, in general, points to upgrade paths of output/innovation capabilities, and adjustments to the external environment, yet the triggers of inventive activities remain under-explored. Firms in emerging markets can build on knowledge from diversified knowledge sources beyond organizational, technological, and geographical boundaries through MNEs' pipelines and personal relationships (Lorenzen & Mudambi, 2013), thereby increasing the chance of knowledge recombination.

In this paper, hence, we aim to address the gap in the catch-up literature by comparing the catch-up in of technological capabilities in case of Korea and Brazil in the context of pharmaceutical industry by looking at the dispersion and density of inventor networks. Korea and Brazil represent the exemplary cases of disparity in catch-up among late industrializing countries (Moreira, 1995). Our data is based on patents granted by the U.S. Patent and Trademark Office (USPTO) during the period 1980 – 2010, with inventors and/or assignees based in Korea and Brazil, respectively. The importance of both dispersion and density speaks to the breadth and quality of innovation networks as inventors in emerging markets seek to recombine knowledge in unique and substantive ways. In the context of emerging market firm catch-up, we would expect to see a process of dispersion via MNE networks, followed by the development of local firm's innovative capabilities. As the catch-up process proceeds, we then posit that the density of inventor networks begins to develop, as the pipelines of knowledge creation begin to strengthen (Lorenzen and Mudambi, 2013).

The contribution of this paper is threefold: first, we enhance the theory of emerging market catch-up with a network theory lens. Second, we build on the nascent emerging market catch-up literature to explore catch-up patterns at the level of the economic actor; that is to say, at the firm or institution level of analysis. We argue that each type of actor may participate in the catch-up process differently, and thus require a different analytical lens. Third, we examine the catch-up process quantitatively rather than descriptively through the econometric model. Fourth, we compare and contrast the catch-up experiences in Korea and Brazil which show a stark difference in terms of catch-up process.

THEORETICAL BACKGROUND

Upgrading & Catch-Up in Emerging Markets

A substantial body of literature have described the rapid technological catch-up of emerging market firms with firms from advanced economies by proactively investing in upgrading their capabilities (e.g., Awate et al., 2012; Kumaraswamy et al., 2012). The key thesis in these studies is that, as Abramovitz (1986) argues, the greater the gap in technology and productivity between emerging and industrialized economies, the greater the potential for "rapid" catch-up. In emerging markets, compared to firms from advance economies, domestic firms are more likely to be technologically and even managerially backward, without much variance in their capabilities and performance (Kumaraswamy et al., 2012). As the firms with sophisticated technology and capability enter the market, domestic firms start to learn from those firms, therefore upgrade their skills and capabilities. Such a rapid catch-up in technological capability allows domestic firms in emerging markets upgrade skills and capabilities, thereby enabling these firms to be competitive in international markets. Giuliani et al. (2005) investigate the upgrading process of domestic firms in Latin America by clustering in industrial districts. Those firms are able to overcome growth constraints through upgrading process–i.e., process upgrading, product upgrading, functional upgrading, and intersectoral upgrading, thereby contributing to global value chains (GVCs). Firms in emerging economeis are able to go beyond production capability, the skillls involved in optimizing the operation of established plants (Amsden, 1989), and eventually achieve innovation capability, the skillls and technologies necessary to create new products or service (Awate et al., 2012).

A key to domestic firms' technological catch-up is the level of technological knowledge embodied in a country's capital stock (Abramovitz, 1986). Through foreign direct investment, MNEs with sophisticated capabilities enter the emerging economies (Kumaraswamy et al., 2012). As a result, knowledge spillovers take place, and there is an increasing chance for domestic firms to learn sophisticated knowledge and skills. To understand and implement sophisticated technologies invented abroad, however, requires that more skills must be build up by domestic workers and managers – i.e., absorptive capacity of the economy (Keller, 1996). Technologies are tacit in nature, and their underlying principles are not always clearly understood (Lall, 1992). Therefore, learning is required for technology transfer. Dahlman, Ross-Larson, and Westphal (1987) show that the probability of a successful technological transfer is highly dependent on if the workers study, train and practice well in advance of the inception of the new project. In a similar vein, Amsden (1989) argues that Hyundai, a South Korean multinational conglomerate, could never quite replicate the shipbuilding process until it began to learn some of the underlying technologies.

Indeed, a substantial amount of literature on newly industrializing countries (NICs) investigate the differences among such countries as to their relative emphasis on human capital as well as technology investment (e.g., Amsden, 1989; Keller, 1996; Moreira, 1995). A relatively high initial level of human capital should be beneficial in the acquisition of new technologies, and if a country moves towards an outward-oriented regime which gives access to new technologies at a higher rate, then a correspondingly higher rate of human capital will be necessary to sustain the process of technological development and higher overall growth. The general hypothesis in this literature is that absorptive capacity is critical for domestic firms' catch-up in emerging markets. In other words, absorptive capacity at a national level as a whole

lay a foundation for the evolution of absorptive capacity at a firm- and an individual level such that the capacity of firms and/or individuals working at firms to create new products or services also increased over time. As catch-up process at a national level, corresponding catch-up process at a firm and an individual level would also take place. In virtue of the outward-oriented government policy which puts greater emphasis on strong commitment to education as well as science and technology (S&T), domestic firms in newly industrializing countries to access to advance economy firms' state-of-art technologies and secure qualified knowledge workers (Amsden, 1989).

Global value chains (GVCs) represent the intersection of the economic geography and strategic management literatures. The firm's value chain consists of the relevant inputs and outputs that yield a productive unit (Porter, 1980), however value creation is largely a function of linkages around the world (Stabell & Fjeldstad, 1998). Global value chains analysis is a tool to examine the web of locations and linkage that comprise economic activity (Gereffi, 1999; Sturgeon, Van Biesebroeck, & Gereffi, 2008).

Advances in technology have enabled the finer slicing of value chain activities, which are increasingly located in efficient locations around the world (Mudambi, 2008). GVC activities may take advantage of tangible and intangible assets (Mudambi, 2008), while firms that orchestrate the interlinked activities generate the greatest value (Dedrick, Kraemer, & Linden, 2010). However, the literature has noted that GVCs also represent a pathway for emerging market economies to participate in global trade: the ability of domestic firms to upgrade skills and make higher level contributions to global value chains is an essential element of emerging market catch-up (Giuliani et al., 2005; Humphrey & Schmitz, 2002). In broad terms, GVCs

represent the higher level networks that emerging market economic actors can learn from, contribute to, and synchronize technological trajectories.

The agglomeration of economic actors is a vital condition of the upgrading process (Giuliani et al, 2005). To the extent that firms cluster in a specialized (Marshall, 1925) or diversified (Jacobs, 1969) manner, there agglomeration externalities that spur on innovation. There has been some debate as to the mechanisms of cluster success (Krugman, 1991), but the gravitational pull of clusters is clear (Baptista & Swann, 1998). However, colocation is not a sufficient precondition for cluster success (McCann & Mudambi, 2005). Our paper firmly adopts the position taken by Giuliani: that is, the growth prospects of a cluster are tied closely to its absorptive capacity (Cohen & Levinthal, 1990; Giuliani, 2005). The ability of a cluster to create and assimilate both tacit and codified knowledge is predicated on its existing stock (Gertler, 2003). The key question as it relates to the catch-up process then, is how does this apply to different types of economic actors.

The mechanisms of cluster success in the catch up context may lie at both the firm and individual levels of analysis. On the one hand, the literature on information relationships in clusters is well established; knowledge flows on the back of informal networks (Saxenian, 2006). Knowledge spillovers have an inherently local bias (Jaffe, Trajtenberg, & Henderson, 1993). However, recent work has shown that organizational "pipelines" enable local spillovers of knowledge (Lorenzen and Mudambi, 2013). It is the very embededness of firms in local clusters that spurs on learning (Malmberg & Maskell, 1997). In this paper, our position is that the networks of both organizations and individuals take on a crucial evolution, and the analysis of those networks is a key determinant of the overall catch-up process (Lorenzen and Mudambi,

2013). The use of external knowledge from either the standpoint of the MNE's recombinatory efforts (Kogut and Zander, 1992) or the unique backgrounds of diaspora (Saxenian, 2006) may suggest that catch-up follows a parallel growth in network diversity and density over time.

It has been noted that a broad knowledge base is crucial for innovation (Bierly & Chakrabarti, 1996). In support of this, Brusoni, Prencipe, and Pavitt (2001) argue that innovative firms know more than they make. Firms with innovation capabilities thus create and leverage knowledge over a wide range of disciplines by tapping into a diverse set of knowledge in foregin locations. This enables the firm to be in a better position to combine knowledge in a more complicated way (Bierly & Chakrabarti, 1996), thereby creating causal ambiguity which increases the sustainability of competitive advantages (Reed & DeFillippi, 1990). For instance, owing to the accumulation of knowledge stores and recombinative capabilities (Kogut & Zander, 1992), MNEs from advanced economies conduct more foreign R&D to tap into a diverse set of external knowledge abroad to improve their competitive position (Berry, 2006). Since inventors from MNEs from advanced economies may have more access to pipelines and personal relationships than emerging market firms (Lorenzen & Mudambi, 2013), they would have greater potential to engage in international collaboration. Geographically dispersed inventor networks may increase the chance of recognizing knowledge recombination opportunities which are crucial for innvoation by allowing collaboration with inventors with different knowledge and perspectives, which in turn influences on catch-up ability of firms in emerging economeis.

Not only the breadth of innovation networks manifested in dispersion matters, but also the quality of innovation networks manifested in density matters for emerging market firms' catch-up process. That is to say, a depth of overall knowledge base which allows a firm to

develop more easily new technologies (Awate et al., 2012) is also important for emerging market firms' catch-up process. Through the continuous experiential learning, firms are able to understand more deeply about the knowledge surrounding the key technologies as well as complementary technologies, which in turn would increase the firms' ability to apply such technologies to innovations (Cohen & Levinthal, 1990), and further identify new knowledge sources in the long run. In support of this, comparing Suzlon and Vestas, an Indian company and a Danish company respectively, Awate et al. (2012) show that Vestas has a broader as well as deeper overall knowledge base which essentially reflects a firm's innovation capability, thus is more capable of recombining technologies in develping new innovations.

A Model of Catch-up

In emerging markets, firms must balance diffusion and internal R&D in order move along the catch-up process (Bell & Pavitt, 1993). In line with this, Kumaraswamy et al. (2012) point out the importance of building relationships with firms from advanced economies on absorptive capacity building, while, Park and Lee (2006) emphasize the importance of in-house learning on absorptive capacity building. As in the case of MNEs from advanced economies, emerging market firms would also broaden network which allows such firms to access to a diverse set of knowledge, which in turn increases the possibility of new combinations and thus enhances the likelihood of emergence of novel ideas. Zander and Sölvell (2000) argue that there exist significant opportunities for cross-fertilization of knowledge across and technologically diversified network of firms. In a similar vein, Henderson and Cockburn (1996) point out the benefits of diversity in research agendas of pharmaceutical firms. They suggest that a wide range of research approaches and expertise within firms permit the cross-fertilization of ideas through

knowledge spillovers between units and therefore greater innovative output. The diversity of technological knowledge resources available to domestic firms in emerging markets will affect the innovation of such firms (Almeida & Phene, 2004) by allowing domestic firms to understand the knowledge in core technology areas as well as in other complementary technologies (Awate et al., 2012). From this perspective, it is reasonable to expect, therefore, that in emerging markets, firms would be more likely to broaden their network via MNE network –i.e., pipelines as well as personal relationships so that they can draw on a broad set of knowledge all over the place and ultimately develop innovative capabilities.

Then, as a firm's absorptive capacity – i.e., the ability to recognize the value of new, external knowledge, assimilate it, and apply it to commercial ends (Cohen & Levinthal, 1990) develops, a firm's network may be evolved to a dense network. Once domestic firms are exposed to a broad set of knowledge, thus increasing the understanding of core technologies as well as complementary technologies, they would be specialize their network, which would reflect the deep understanding of the technologies. Therefore, we expect that as absorptive capacity at a national level evolves, emerging market firms' network would evolve from board network to dense network over time.

To sum up, a catch-up process model in emerging market firms would be manifested graphically in figure 1:

Insert Figure 1 about here

METHODOLOGY

Research Context

In this study, we compare the catch-up of technological capabilities in case of Korea and Brazil. Korea and Brazil represent the exemplary cases of disparity in catch-up among late industrializing countries (Moreira, 1995). Government policy plays a crucial role on their catch-up process: the different orientation of government intervention and the extent of government intervention results in different patterns of education and training of the labor force, technology acquisition, commitment of resources to technological learning (Viotti, 2002), thereby leading to different path of catching-up and resultant chance for successful catch-up. There is a fundamental distinction between a strategy where intervention was guided and disciplined by the aim of international competitiveness. Specifically, outward-oriented Korean government puts greater emphasis on strong commitment to education as well as science and technology (S&T) (Moreira, 1995), thus laying the foundation for Korean firms to build and upgrade their competencies by conducting internal R&D essential for innovation. However, inward-oriented Brazilian government produced a weak local private sector, a poorly qualified workforce and poor S&T infrastructure (Moreira, 1995). A different orientation of governments toward their economies inevitably results in very different types of technological effort such that Korean firms rely more on internal capability building, whereas, Brazilian firms heavily rely on FDI which might be beneficial just for production capabilities. Such a stark difference provides us with an exceptional context for studying the different path of catch-up process across two countries.

Data

Our data is based on patents granted by the U.S. Patent and Trademark Office (USPTO) during the period 1980 – 2010, with inventors and/or assignees based in Korea and Brazil, respectively. Despite of some criticism, patents are known to represent firms' inventive activity, and thus, are frequently used for the analysis of the process of technological change (e.g., Awate et al., 2012; Cantwell & Zhang, 2013; Griliches, 1998). Observation of our data consists of 1,124 (Korea) and 430 (Brazil) focal patents respectively.

Measures

Dependent variable

As a dependent variable, following Borgatti (2005)'s closeness centrality measure which is based on the inverse of the distance of each actor to every other actor in the network, we construct network density.

Independent variables

First, drawing on Kollmann and Mudambi (2013), we construct the geographical dispersion of the network of inventors. The Herfindahl index of inventor concentration at the country level is calculated. Since our interest lies in the dispersion of inventor networks rather than concentration of inventor networks, we compute the dispersion index by 1 minus Herfindahl index, therefore, dispersion index has a minimum value of 0 and a maximum value of 1. Second, as policy indicators which reflect the different orientation of two countries, we use variables such as GDP/export, research and development expenditure (% of GDP), researchers in R&D (per million people) which are drawn from the World Bank. Third, assignee type dummies – i.e., foreign firms, foreign institutions, domestic firms, domestic institution, and private inventor-assignees are used.

Model

Our model is following:

$$Density_t = \beta_0 + \beta_1 Dispersion_{t-1} + \beta_2 Policy_{t-1} + \beta_3 Assignee\ type$$

Some preliminary results

Our data shows that Korea shows a greater number of pharmaceutical patents granted in the US than Brazil. Table 1 displays the number of USPTO patents with links to both countries over five year periods. While patenting in both countries rises dramatically after the implementation of TRIPS, Korea's growth far surpasses that of Brazil. The inventor dispersion index is displayed in Tables 2-5, and is divided amongst assignee types: foreign firms, foreign institutions, domestic institutions, domestic firms, and private inventor-assignees. In the post-TRIPS period, Brazilian inventors have largely lagged behind Korean inventors with respect participation in MNE knowledge networks.

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Figure 1. A Model of Catch-up

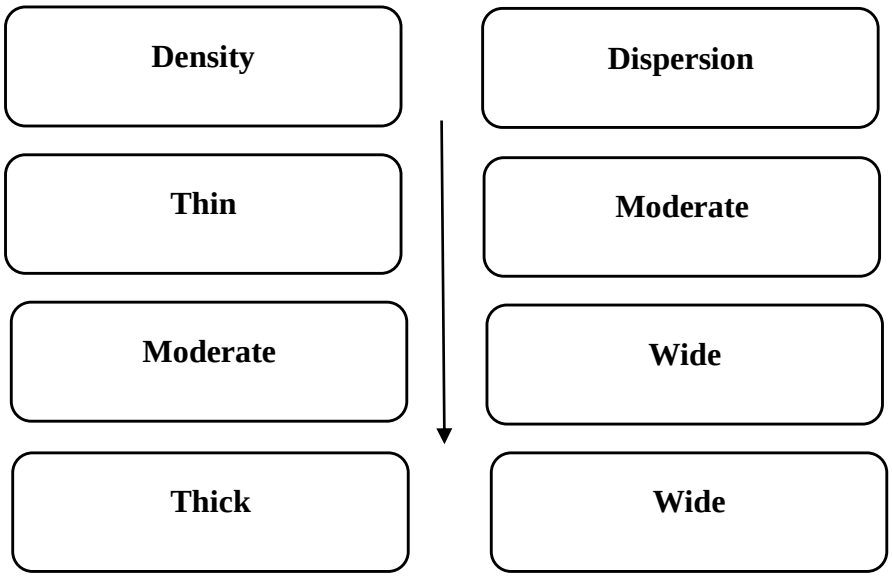

Table1: Number of USPTO Patents with links to Korea and Brazil, 1980-2010

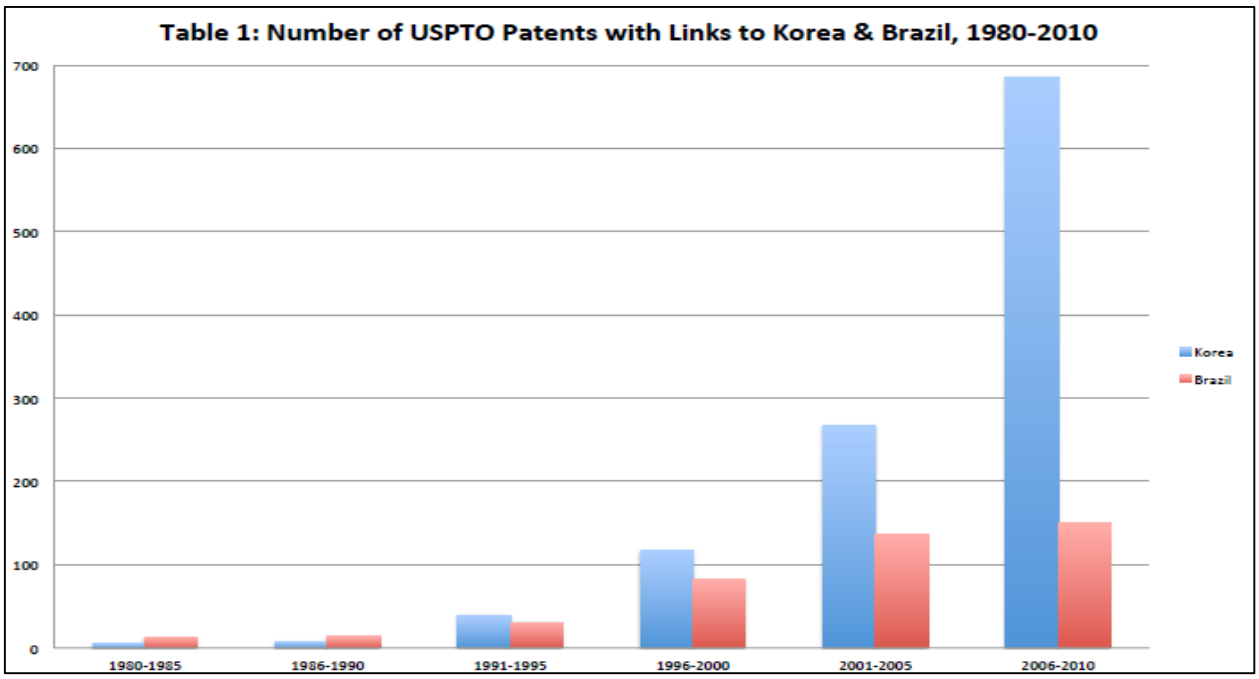

Table2: Inventor International Dispersion, Foreign MNE 1980-2010

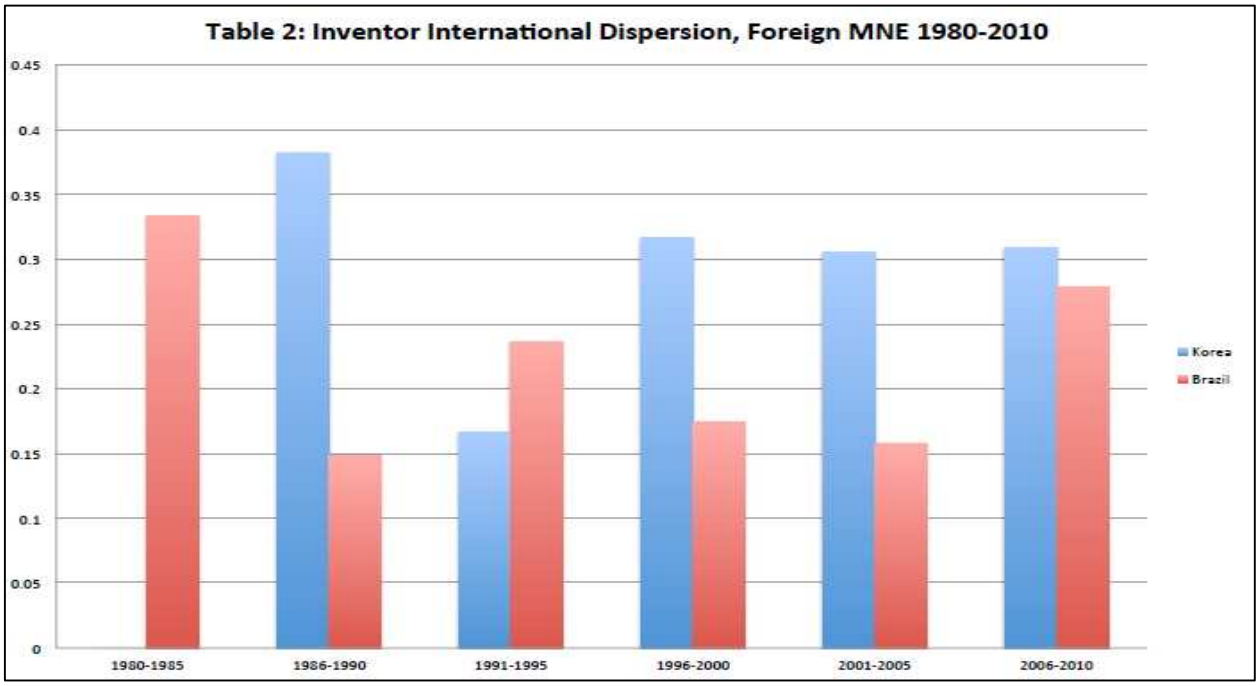

Table3: Inventor International Dispersion, Foreign Institutions, 1980-2010

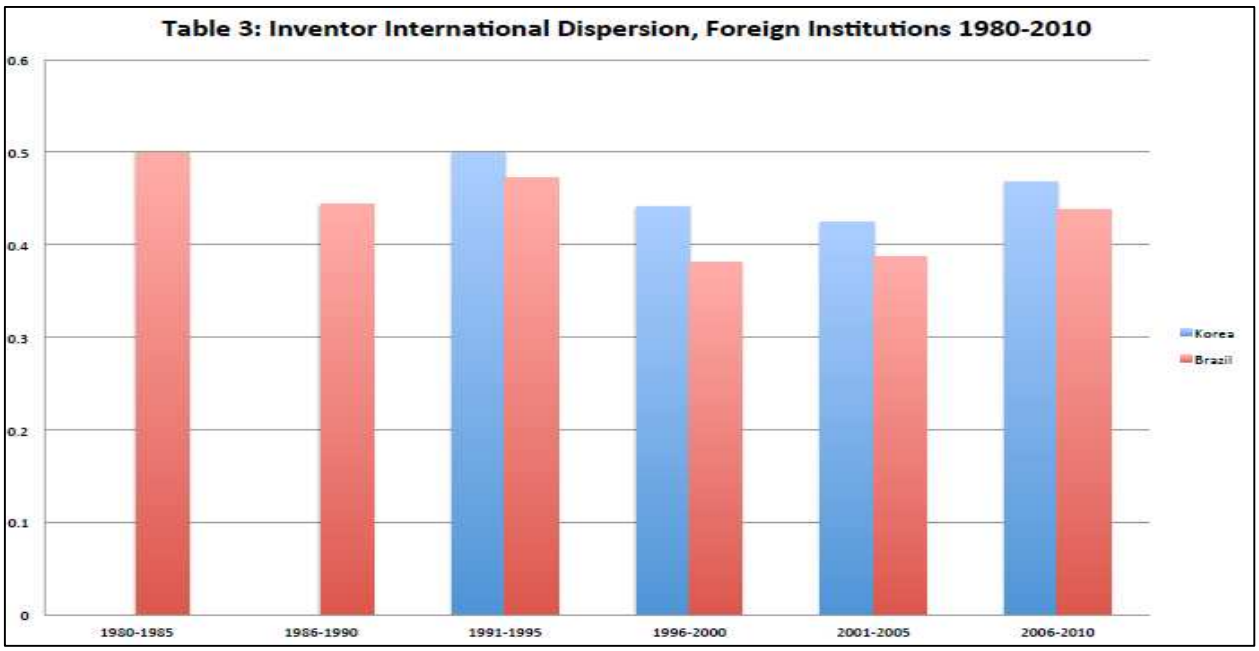

Table4: Inventor International Dispersion, Domestic Institutions, 1980-2010

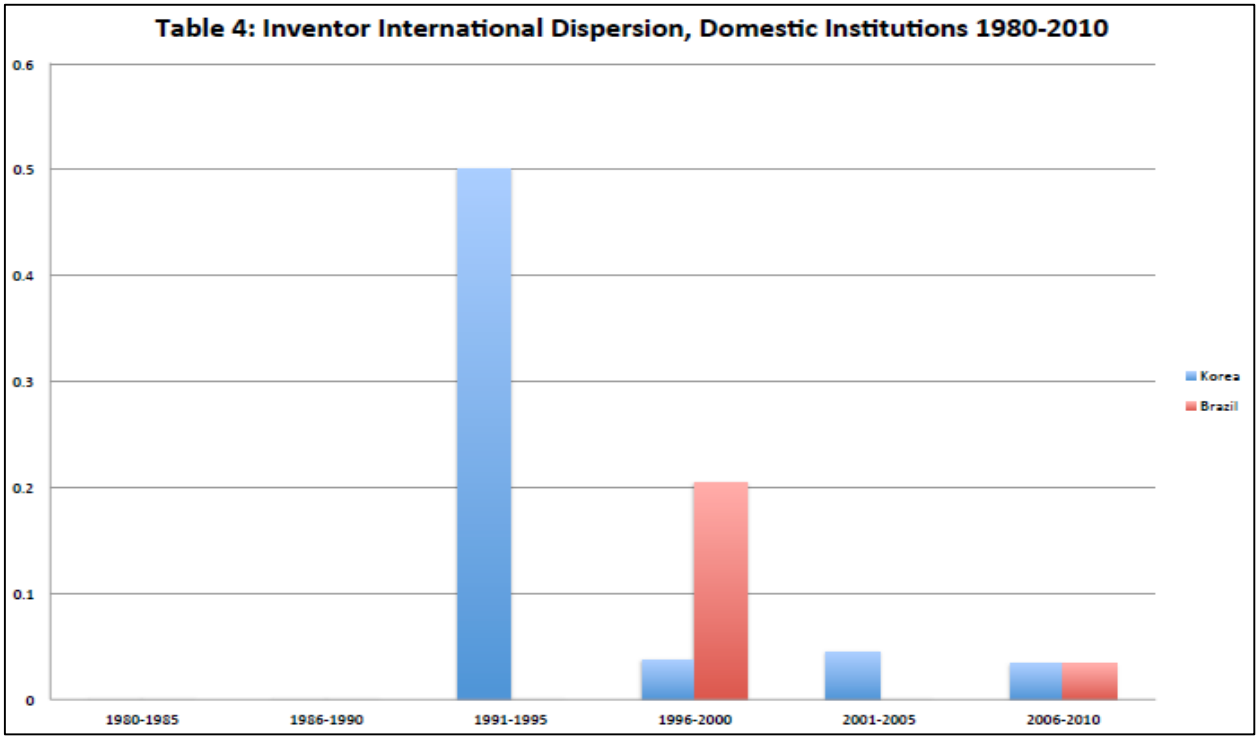

Table5: Inventor International Dispersion, Domestic Firms, 1980-2010