NEW TECHNOLOGY DEVELOPMENT IN EMERGING ECONOMIES: AN EXAMINATION OF THE ANTECEDENTS OF INTERNATIONAL PATENTING ACTIVITIES OF EMERGING ECONOMIES

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ABSTRACT

This dissertation investigates the phenomenon of new technology development in emerging economies (EEs). I do this by studying the international patenting activities of EEs at the country level and firm level. In order to do this, I develop and analyze a panel database of patents filed with the United States Patents and Trademarks Office (USPTO). I then examine differences in the nature of technologies that are being patented by emerging economies in comparison to developed economies (DEs). Through this dissertation, I develop a key construct that pertains to the nature of technologies that are patented. This construct is named novelty of technology knowledge and it pertains to the age of technological knowledge that organizations draw from and build upon while developing new innovations.

The first research question I examine is what is the impact of global connectedness and institutional development in EEs on the age of technology knowledge that they build on. I build on insights from the institutional theory and argue that the absence of well-developed institutions presents constraints to the development and protection of novel technology innovations. On the other hand, global connectedness in the form of trade linkages provides opportunities for engaging in novel technology innovations. I hypothesize that a country's level of institutional development and global connectedness have a positive relation with the novelty of its technology knowledge. I use data on the international patenting activities of 48 countries with the USPTO over a period of 9 years. I use panel data estimation models to test the hypotheses. I find that global connectedness is positively related to the level of a country's international patenting.

The second research question is what is the impact of the level of internationalization of EE firms on the age of technology knowledge that they build on. I first identify the benefits and costs associated with internationalization for EE firms as a result of the conditions in their home country. I then argue that with increasing internationalization, the counter forces of exploration and exploitation thrust firms' technology development from initially focusing on newer technology bases towards focusing on older technologies. I hypothesize the existence of a U-shaped relationship between the level of internationalization and the novelty of technology knowledge and test my hypotheses using a panel of bio-pharmaceutical firms from India. The findings from this dissertation make important contributions to the literature examining innovation and new technology development in the context of EEs.

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GENERAL ABSTRACT

This dissertation investigates the phenomenon of new technology development in emerging economies (EEs). I do this by studying the international patenting activities of EEs at the country level and firm level. In order to do this, I develop and analyze a panel database of patents filed with the United States Patents and Trademarks Office (USPTO). I then examine differences in the types of technologies that are being patented by emerging economies in comparison to developed economies (DEs) and find that different countries focus on innovations in different types of technologies.

The first research question I examine is what is the impact of global connectedness and institutional development in EEs on the technologies that they patent. I find that a country's level of global connectedness is positively related to its level of international patenting. The second research question is what is the impact of the level of internationalization of EE firms on the technologies that they patent. I find that with increasing internationalization, firms' technology development shifts from initially focusing on newer technologies towards focusing on older technologies.

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CHAPTER 1: INTRODUCTION

Emerging economies (EEs) are typically latecomers to the global marketplace and are faced with the challenge of competing in the same technological space as developed economies (Bartlett & Ghoshal, 2000; Kothari, Kotabe, & Murphy, 2013). In addition, most EEs are characterized by lower levels of economic, human capital, and institutional development as compared to developed economies (Hoskisson, Eden, Lau, & Wright, 2000; Hoskisson, Wright, Filatotchev, & Peng, 2013). Despite this, increasing levels of patenting and increasing involvement in new technology development (UNCTAD, 2013) demonstrate that EEs are developing their technological capabilities despite these competitive and institutional challenges that they face. Accordingly, the broad research objective that guides this dissertation is *to understand the factors contributing to this phenomenon of new technology development in emerging economies.*

Research examining new technology development at the country level has identified factors such as R&D expenditures and human capital in R&D (e.g., Teitel 1994; Furman, Porter & Stern, 2002) the strength of public research and higher education institutions (Mazzoleni & Nelson, 2007) and industrial clusters (Furman et al., 2002) in explaining the level of innovative output generated by different countries. While much of this prior research has focused on the level of patenting, there are significant gaps in our understanding of the nature of technologies that are patented. The development of new innovations varies depending upon the types of technologies that organizations choose to focus on (Danneels, 2002; Jansen, Van Den Bosch, & Volberda, 2006; Subramaniam & Youndt, 2005). New innovations in mature, well understood technologies require a different set of capabilities than innovations in novel, emerging technologies (Zhou & Wu, 2010). Further, while some literature argues that new technology knowledge is crucial for developing innovations since older knowledge becomes obsolete and cannot meet the needs of markets (e.g., Eisenhardt, 1989; Thompson, 1967), other literature argues that older, well established knowledge is more reliable (March, Sproull, & Tamuz, 1991) and hence can be used to develop new innovations.

Indeed, emerging economies are at the forefront of innovations in some cutting edge technologies (e.g., Awate, Larsen, & Mudambi, 2012) whereas in other areas rely on imitative innovations in older technologies (Luo, Sun, & Wang 2011). This dissertation examines this interesting phenomenon of new technology development in EEs as demonstrated by their international patenting activities at the country level and firm level. Specifically, I examine two research questions through two separate studies with the following research questions:

- *At the country level, what is the impact of global connectedness and institutional development in EEs on the level and novelty of technologies that they patent?*
- *At the firm level, what is the impact of EE firms' level of internationalization on the novelty of technologies that they patent?*

Study 1 (detailed in Chapter 3 of this dissertation) consists of an examination of the first research question. To do this, I first examine whether there are any differences in the age of technologies that are patented by different countries. Upon finding significant differences in the average age of technologies that different countries patent in, I then examine the reasons for these differences in the age of technologies. To do this, I build upon the institutional theory perspective that identifies factors such as educational and political institutions (Varsakelis, 2006), control of corruption, market-friendly policies, protection of property rights (Varsakelis, 2001; Tebaldi & Elmslie, 2013), and efficient equity markets (Hsu et al., 2014) that impact innovation.

I argue that the differences in institutional conditions across countries lead to differences in the patenting behavior of countries by influencing the incentives offered to the development and protection of intellectual property. Specifically, I hypothesize that the lack of strong *institutional systems* in a country present *constraints to innovation in novel technologies*. In addition, I also argue that the degree to which a country is connected to the global marketplace affects the ability to develop new technology by influencing the accessibility to knowledge and resources - both financial and human - necessary for the development of patentable innovations in different types of technologies. Here, I hypothesize that a country's *global connectedness* provides *incentives to innovation in novel technologies.*

Study 2 (detailed in Chapter 4 of this dissertation) pertains to the factors that influence innovations in novel technologies at the firm level. Firms from emerging economies are actively engaging in the development of innovations as demonstrated by the increasing number of patents that they have been granted over the past few years (WIPO, 2015). In addition, there is also evidence that EE firms are internationalizing rapidly as demonstrated by the increasing levels of outward FDI from EEs (UNCTAD, 2013). This study examines the impact of EE firms' internationalization activities on the age of the technologies that they patent.

Much of the older internationalization literature, that examined international activities of firms from developed economies, explained international expansion as the means of exploiting internationally the firm specific advantages (FSAs) that firms held in their domestic operations (Dunning, 1980; Hymer, 1976). Recent literature - that examines firms from EEs - argues that international expansion by firms is also driven by the need to acquire the FSAs that they lack at home (Child & Rodrigues, 2005; Luo & Tung, 2007). Especially in the case of EE firms - since these firms are behind the technology frontier owing to their country of origin -

internationalization serves as a strategy to acquire technological assets that cannot be accessed at home (Gubbi et al., 2009; Makino, Lau, & Yeh, 2002; Yiu, Lau, & Bruton, 2007).

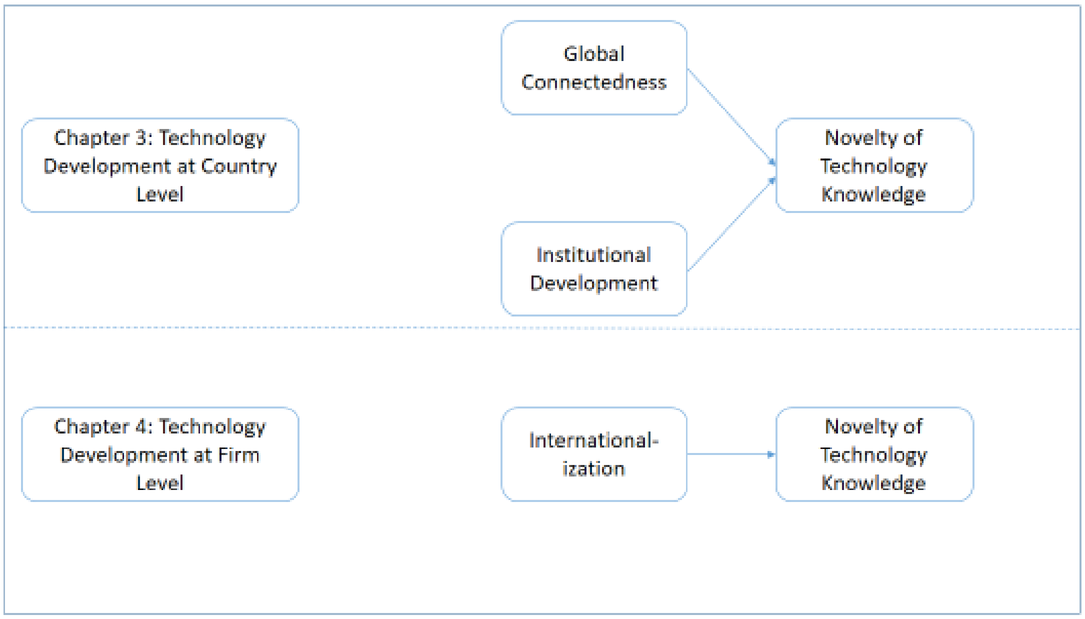
This makes it important to identify the impact of the international activities of EE firms on their innovation at home. In order to do this, I first identify the benefits and costs associated with internationalization for EE firms as a result of the conditions in their home country. While internationalization provides firms with opportunities to explore and acquire foreign technology knowledge it also presents higher costs of coordination and complexity arising from the increased scope of international operations. Accordingly, I hypothesize the existence of a U-shaped relationship between level of internationalization and the novelty of technology knowledge.

In order to better understand the nature of technologies that EEs focus on, I develop the key construct called age of technology knowledge. The development of this key construct is an important contribution of this dissertation. This construct pertains to the mean age of technological knowledge that EEs build upon in order to develop new, patentable innovations. An examination of technology knowledge is important because it is one of the key sources of competitive advantage (Criscuolo, Narula, & Verspagen, 2005; Porter, 2011). In addition, different types of technology knowledge can provide different kinds of competitive advantage. Old knowledge is considered to be reliable and legitimate (Katila, 2002; March, 1991) and can lead to innovations in mature technologies. On the other hand, novel knowledge offers opportunities for breakthrough innovations and prevents obsolescence (McGrath, 1999; Sorensen & Stuart, 2000). Thus the age of technology knowledge represents its novelty and consequently its potential to generate competitive advantage. Further, the capabilities required for developing innovations using different types of knowledge are different (Zhou & Wu, 2010). Thus, an examination of the novelty of technology knowledge developed by EEs is important for understanding how EEs manage the challenges of innovation while trying to stay competitive in the global marketplace.

Accordingly, I examine the key dependent variable i.e. the novelty of technology knowledge of EEs at the country level (Chapter 3) and at the firm level (Chapter 4). To measure the novelty of technology knowledge, I use data on all patents filed with the USPTO and calculate the age of the knowledge that these patents build on. At the country level, I use data on international patenting activity of 48 countries with the USPTO. I also use data on measures of economic and institutional development of these countries over a period of 9 years from the World Development Indicators and the US Government Census database. I develop a panel dataset and use the Arellano–Bover/Blundell–Bond linear dynamic panel-data estimation to test my hypotheses. At the firm level, I test my hypotheses in the context of biopharmaceutical firms from India. I collect internationalization location data from firms' annual reports and code the number of foreign subsidiaries for each firm to calculate their level of internationalization. I use firm level information on firm sales, profitability, and age from the Prowess Database published by Center for Monitoring Indian Economy (CMIE). I develop a panel of firm level data over 16 years and use a zero inflated negative binomial regression model to test my hypotheses.

Figure 1.1 depicts a conceptual model of the relationships I study through the dissertation. At the country level, at the onset, I find significant differences in the level of international patenting by EEs versus DEs and in the mean age of the technologies that they patent. Further, I hypothesize that a country's level of global connectedness and institutional development will have a positive relation with the level of its international patenting and novelty of its technology knowledge. I find that global connectedness is positively related to the level of a country's international patenting.

Fig. 1.1: Conceptual Model of Dissertation



At the firm level, I hypothesize and find the existence of a U shaped relationship between internationalization and the novelty of technology knowledge in that the age of a firm's knowledge first decreases with internationalization to reach a minimum age after which the age of a firm's knowledge increases with further internationalization. I also theorize the underlying mechanisms that jointly make up this U shaped relationship that pertain to the costs and benefits associated with internationalization and innovation.

The findings from this dissertation make important contributions to the literature examining innovation and new technology development in the context of EEs. While most prior research examines differences in the absolute level of new technology development, this dissertation recognizes that the development of different types of technologies requires different capabilities and consequently offers different opportunities for competitive advantage. By examining the reasons why the technologies that EEs focus on are different from the ones that DEs focus on, I highlight the differences in capabilities and the implications of these differences on competitiveness. Thus this dissertation provides evidence of the different paths that EEs take in order to develop competitive advantage and suggests a contingency perspective on understanding innovation in EEs.

The key construct of novelty of technology knowledge developed through this dissertation allows for a more fine grained understanding of the process of technology development than has been provided by prior research. Further, the examination of the antecedents of technology development in the form of global connectedness, institutional development, and firm internationalization provides insights about the factors that impact the knowledge that EEs can access and build on while developing new innovations.

Lastly, the dissertation contributes to the growing literature on emerging economies and firms from EEs. While most existing literature utilizes case based, qualitative, and single country study methodologies, this dissertation make important quantitative contributions by using a multi country, multi industry approach to contribute to the breadth of our understanding, as well as a single country, single industry approach to provide detailed insights into EE firm strategies.

The findings from this dissertation also have significant implications for firms and public policy by providing recommendations to EE governments about the importance of institutional support and the factors that influence innovations in different types of technologies. Further it provides prescriptions to EE firms attempting to internationalize by providing evidence about the impact of internationalization on their technological capabilities and subsequent innovation.

CHAPTER 2: LITERATURE REVIEW

2.1 Literature on Emerging Economies

What are Emerging Economies?

An emerging economy can be defined as "a country that satisfies two criteria: a rapid pace of economic development, and government policies favoring economic liberalization and the adoption of a free market system" (Arnold & Quelch, 1998). Hoskisson et al. (2000) define emerging economies as 'low-income, rapid-growth countries using economic liberalization as their primary engine of growth'. An emerging economy is also described as "a society transitioning from a dictatorship to a free-market-oriented-economy, with increasing economic freedom, gradual integration with the global marketplace and an expanding middle class, improving standards of living, social stability and tolerance, as well as an increase in cooperation with multilateral institutions (Kvint, 2009). Emerging economies are considered to be "regions of the world that are experiencing transformation under conditions of limited or partial industrialization" (Centre for Knowledge Societies, 2008). On the whole, emerging economies (EEs) have seen a remarkable transformation in recent years marked by rapid growth (UNCTAD, 2013) and are now gaining an important position in the world economy on the whole.

The increasing proportion of global foreign direct investment inflows to these economies has led to a major restructuring of the global economy, and consequently these countries now present major growth opportunities to businesses as a result of this evolution of the world economic order (Arnold & Quelch, 1998). Brazil, Russia, India, and China (BRIC countries) are widely considered to be the four largest emerging economies by gross domestic product (GDP). South Africa, Mexico, and, Turkey are some other countries also known to be considered as emerging economies. These countries are categorized as emerging economies based on various characteristics such as the level of economic development, growth rate, national investment risk or rate of liberalization (Arnold & Quelch, 1998), or also based on how well an economy helps buyers and sellers come together (Khanna & Palepu, 1997). The following section details the classification of countries.

Classification of Countries as Emerging Economies

Hoskisson et al. (2000) identify 51 rapidly growing developing countries and 13 *transition economies* (the ones that are in transition from centrally planned economies) – a total of 64 emerging economies. In 2012, as a result of the continuing changes in the global environment, Hoskisson et al. (2012) reclassify countries along two dimensions: (1) institutional development and (2) infrastructure and factor market development to develop a classification of emerging economies into the categories of traditional emerging economies, mid-range emerging economies, and newly developed economies.

A number of different organizations classify countries into various categories using different criteria as the basis for classification. A few are detailed below. The International Monetary Fund (IMF) uses countries' export earnings to classify countries as emerging market and developing economies, and advanced economies (IMF, 2015). The FTSE's classification uses criteria such as per capita income, the quality of regulation, and access to financial markets amongst others as key criteria (FTSE, 2015). The Emerging Market Global Players (EMGP) project by Columbia University classifies countries based on trade and FDI rankings (EMGP, 2012). The S&P Dow Jones Indices use country credit ratings, market accessibility, and FDI regulations amongst others as criteria for classification (S&P, 2013). Table 2.1 lists the countries that are classified as emerging economies by these different organizations. As it can be seen from this table, the different criteria used by different classification agencies leads to different countries being considered as emerging economies. Further, since this classification is dynamic, some countries may move to the advanced economy category over time.

Table 2.1: List of Emerging Economies by Different Classification Organizations

IMF	FTSE	S&P Dow Jones	EMGP
Argentina			Argentina
Bangladesh	Bangladesh		
Brazil	Brazil	Brazil	Brazil
Bulgaria			
Chile	Chile	Chile	Chile
China	China	China	China
Colombia	Colombia	Colombia	Colombia
	Czech Republic	Czech Republic	
	Egypt	Egypt	Egypt
	Greece	Greece	
Hungary	Hungary	Hungary	Hungary
India	India	India	India
Indonesia	Indonesia	Indonesia	
			Israel
Malaysia	Malaysia	Malaysia	
			Mauritius
Mexico	Mexico	Mexico	Mexico
Pakistan	Pakistan		
Peru	Peru	Peru	
Philippines	Philippines	Philippines	Philippines
Poland	Poland	Poland	Poland
		Qatar	
Romania			
Russia	Russia	Russia	Russia
			Slovenia
South Africa	South Africa	South Africa	South Africa
			South Korea
	Taiwan	Taiwan	Taiwan
Thailand	Thailand	Thailand	Thailand
Turkey	Turkey	Turkey	Turkey
Ukraine			
	United Arab Emirates	United Arab Emirates	United Arab Emirates
Venezuela			

Characteristics of Emerging Economies

Emerging economies and the markets therein are now being increasingly pursued by businesses as a result of the tremendous growth opportunities outside of the developed world and the subsequent revenue generating potential that these markets present. There are a number of differences between the markets that developed country firms traditionally catered to and the new emerging markets. Many of these differences arise due to differences in the institutional and infrastructural conditions between EEs and DEs (Meyer, Estrin, Bhaumik, & Peng, 2008). Thus EEs provide both opportunities and challenges to firms and the conventional wisdom about global capabilities and transnational strategies may not be applicable in this context (London & Hart, 2004). As a result, firms devise their strategies and activities in response to these institutional and infrastructural conditions and the changes in the marketplace.

As an extension of these new strategies and businesses, there is also a need for fresh perspectives of research that look specifically at EEs and take into account their uniqueness while developing and testing new theories (e.g. Luo & Tung, 2007; Kumar, Mudambi, & Gray, 2013). The literature on business strategy in emerging economies is still in the nascent phase and has not yet effectively addressed all the aspects that surround the question of how firms successfully enter and sustain competitive advantage in these markets (Cuervo-Cazurra, 2012; Hoskisson et al., 2012). The unique characteristics of emerging economies that differentiate them from developed economies demonstrate the need for research examining business in EEs. This entails a discussion of what are the unique characteristics of EEs that differentiate them from DEs. These characteristics are discussed below along with some trends about the economic, infrastructural, and market conditions in EEs.

Economic development in EEs

At present, emerging economies might not show promising absolute numbers of economic development as compared to developed markets, nevertheless, they do show high projected growth rates (Govindarajan & Trimble, 2012). EEs constitute a significant proportion of the world population and as such present tremendous potential as untapped markets (Prahalad, 2005; 2011). Further, most EEs have witnessed significant deregulation and privatization over the past few decades and hence have become more attractive locations for doing business. However, the new opportunities in these markets also present new challenges due to the unique conditions present in EEs. They primarily include weaknesses in the political and legal institutions, cost sensitivity of markets, the dominance of social systems and underdevelopment of infrastructure.

Fig 2.1: Per Capita GDP of EEs and DEs

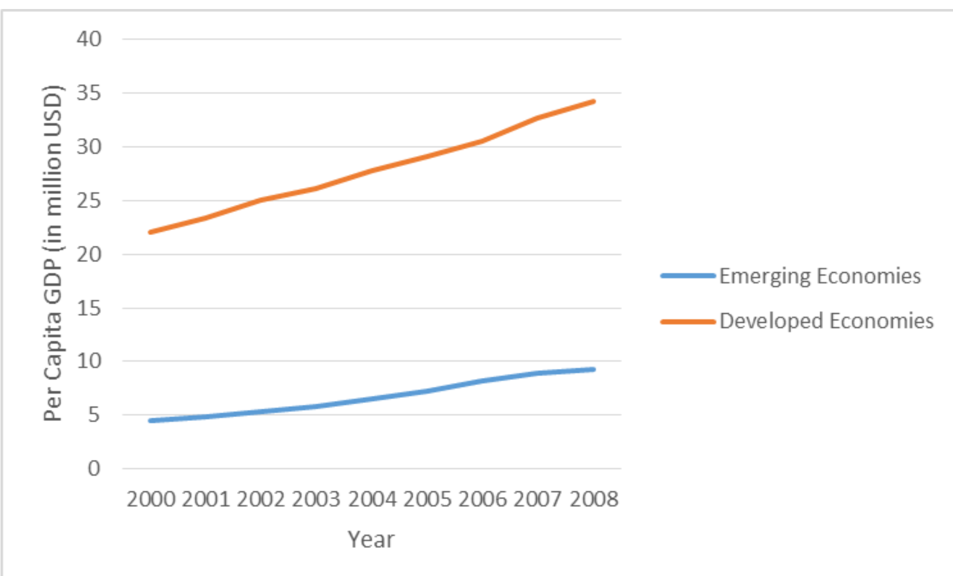
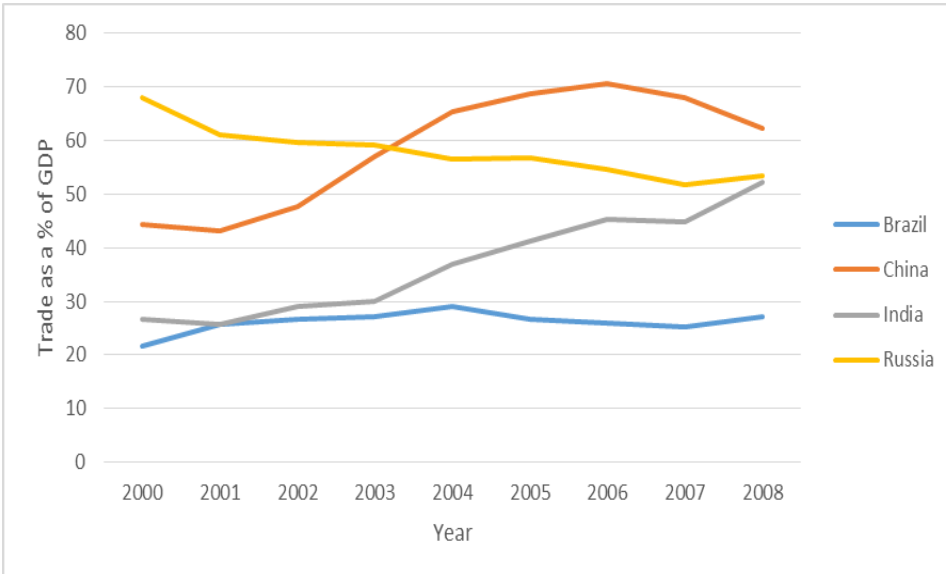


Figure 2.1 shows the GDP per capita in millions of US dollars of emerging economies from 2000 to 2008 in comparison with that of developed economies (data from the World Development Indicators database). Although the absolute levels of GDP of EEs are still much

lower than that of developed economies, the slope of growth implies rapid economic development of EEs.

Fig 2.2: Trade as a percentage of GDP of select EEs



With respect to international trade, figure 2.2 shows the values of trade as a percentage of GDP of the BRIC countries from 2000 to 2008 (data from the World Development Indicators database). This graph capture trade as a sum of exports and imports of goods and services measured as a share of gross domestic product. Except for Russia, all the other countries seem to show an upward trend in terms of trade. This demonstrates an increase in the global connectedness of these economies with the rest of the world. This also suggests that globalization and the reduction in trade barriers world over and especially in EEs has also contributed to economic development (Inikori, 2002).

Fig 2.3: FDI Inflows for EEs and DEs

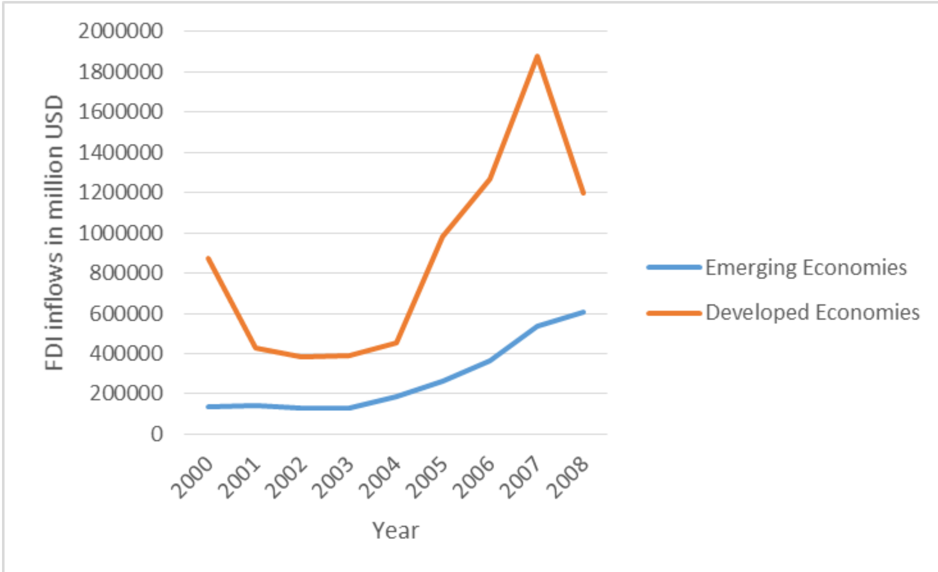
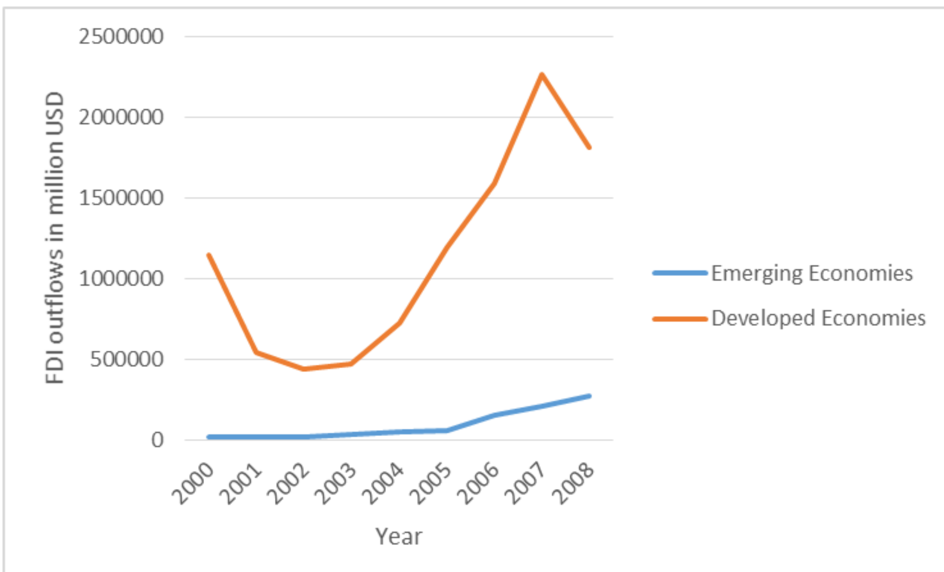


Fig 2.4: FDI Outflows for EEs and DEs



With respect to international investment in EEs, figures 2.3 and 2.4 show the trends in foreign direct investment (FDI) inflows and outflows for EEs and DEs in millions of US dollars. The data from the World Development Indicators (WDI) database from 2000 to 2008 show much variability in the case of DEs and a sharp decrease since 2007 that may be attributed to the 2008 recession. On the other hand, FDI inflows and outflows both have been on a steady increase for

EEs. Thus, the increase in investment flows to and from these countries also provides evidence of the economic development of EEs (Stiglitz, 2000).

Institutional conditions in EEs

Institutions play an important role in determining firm strategies and activities since they influence organizational routines (Boyer & Hollingsworth, 1997; Feldman & Rafaeli, 2002) and are instrumental in shaping the way firms frame strategic choices (Peng, 2003; Peng, Wang, & Jiang, 2008; Powell, 1991). Institutions in EEs are not as stable as the ones in DEs (Young, Peng, Alstrom, & Bruton, 2008) and hence, firms tend to rely on informal institutions (Peng & Heath, 1996) such as those developed through their relational ties, family connections or business groups. As a result of these institutional differences, firm activities in developed and emerging economies differ considerably.

With respect to the role of governments in EEs, there is a high degree of governmental intervention in firms' activities, and the unpredictability of government policies and bureaucracy makes it difficult for firms to navigate operations (Khanna & Palepu, 1997). On the other hand, since the regulatory systems in EEs are less developed, they present fewer delays and lesser friction when companies bring innovative solutions to the market (Govindarajan & Trimble, 2011). Weak institutional systems lead to higher transaction costs that reduce efficiency of firms (North, 1991; Wright, Filatotchev, Hoskisson, & Peng, 2005). Weaknesses in the political and legal systems present challenges to the innovativeness of firms. Changes in the political conditions in EEs may lead to sudden, unpredictable public policy decisions which can seriously impair the long term strategies, and investments of firms.

The state of the legal system of an economy determines the transaction costs to firms (Coase, 1937; 2007) in that weaker legal systems present higher transaction costs. EEs in general do not show the presence of exhaustive regulations with respect to patent laws and intellectual property rights (Peng et al., 2008) which might reduce the barriers to imitation significantly and thus make innovation an unfavorable strategic choice. Enforcement of contracts and resolution of disputes is more difficult in emerging economies. EEs are also generally considered to be apathetic towards intellectual property rights protection, and are tolerant towards counterfeiting, fake goods, and piracy, and other forms of IP rights infringements (Wang, 2011).This poses significant challenges for innovating firms which have very few ways of safeguarding their proprietary knowledge which can potentially give them a competitive advantage in the market (Grant, 1996; Zhao, 2006).

Infrastructure conditions in EEs

There are significant differences between developed and emerging economies in terms of the physical infrastructure that these countries possess. Developed markets have a strong and reliable infrastructure in place which gives an impetus to the introduction and implementation of new technologies and products. However there are many constraints in EEs since the infrastructure development is not as extensive (Banerjee, Oetzel, & Ranganathan, 2006). The underdeveloped physical infrastructure in EEs makes it difficult for production processes, and other firm activities to be carried out efficiently. Despite these differences in the absolute levels of infrastructure development in EEs and DEs, EEs are making significant progress in some aspects of infrastructural development as can be seen from the graphs below.

Fig 2.5: Cellphone subscribers per 100 people in select EEs

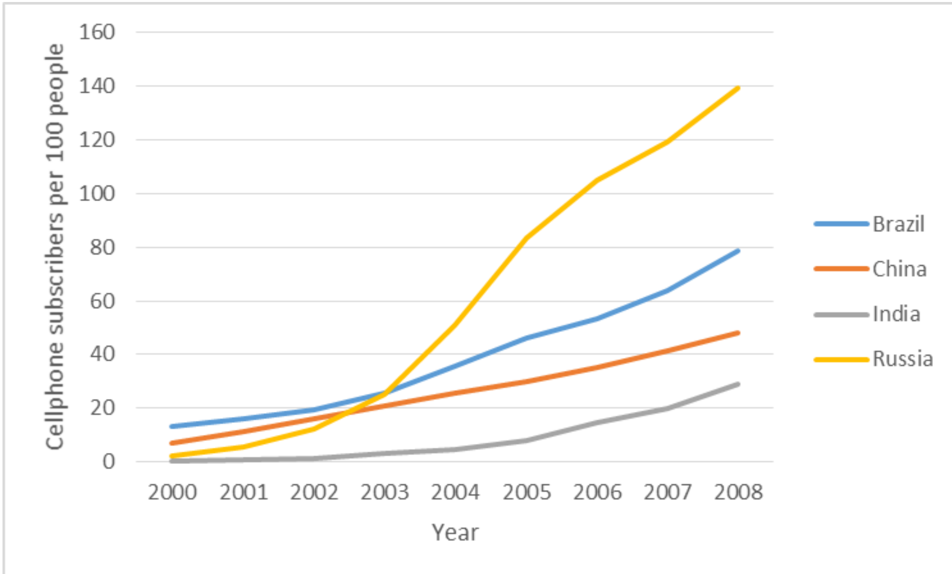


Figure 2.5 shows the number of cellphone subscribers per 100 people in a country from the years 2000 to 2008 in the BRIC countries (data are from the WDI database). It is evident that the level of connectivity in these countries is increasing rapidly due to advances in cellular technology. EEs are said to have leapfrogged DEs in their adoption and usage of cellular technology (Kalba, 2008).

Fig 2.6: Internet users per 100 people in select EEs

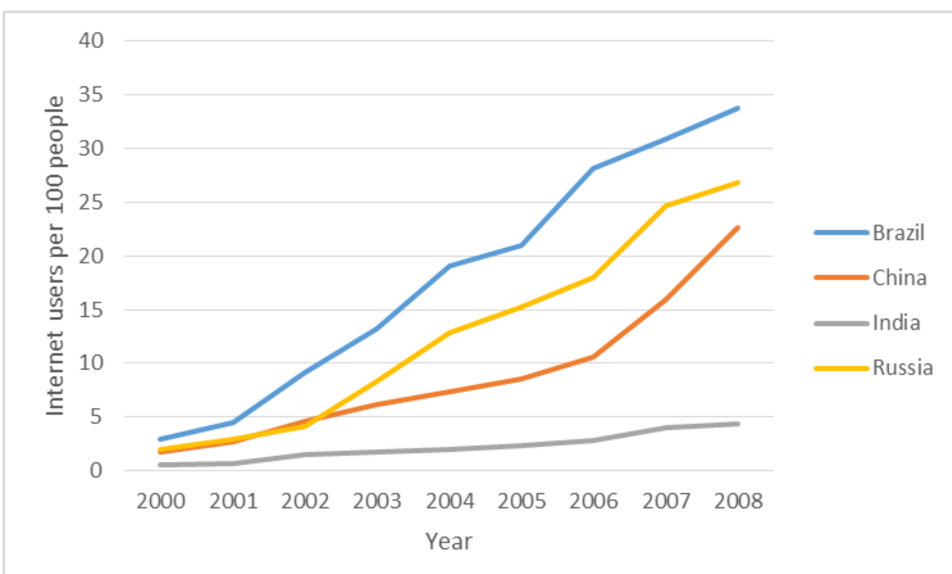


Figure 2.6 shows the number of internet users for every 100 people in the BRIC countries (data are from the WDI database). All of these countries seem to demonstrate a rapid increase in internet usage especially Brazil, Russia, and China more so than India. These graphs illustrate that although EEs still lag behind DEs in terms of traditional infrastructure such as means of transport they are making rapid advancements in technological infrastructure using the internet and telecommunication.

Market conditions in EEs

EEs consist of fast growing economic systems of small enterprises, unregistered assets, and small scale sustainable activities (London & Hart, 2004). The tastes and preferences of EE markets are different from those of the developed world (Cui & Liu, 2001; Dawar & Chattopadhyay, 2002). These markets show immense potential and demand, but they are often served by low quality vendors or predatory suppliers and intermediaries; this suggests the tremendous opportunities present in these markets (Prahalad, 2005).

The presence of an informal economy that is excluded financially from the formal economy leads to the existence of unique social institutions that operate within the emerging markets wherein social contracts and social institutions dominate over legal contracts and formal, legal institutions (London & Hart, 2004). Firms in EEs have to bridge these formal and informal economies in order to bring scalability to their products. This presents a unique challenge of understanding and leveraging the existing social infrastructure by developing networks with these social systems and incorporating fine grained information from them while developing innovative products tailored to the needs of the markets.

Another important difference in the approach towards EEs is the focus on cost sensitive solutions and sustainable innovations. The scarcity of traditional resources faced by EEs, which are utilized in plenty by developed markets, makes for the need of environmentally sustainable, green solutions (Govindarajan & Trimble, 2012). Also many markets tend to be cost sensitive hence necessitating the development of affordable products offering basic features and functionality (Ray & Ray, 2010). Also since economic, social, and environmental considerations are interconnected, economic development and poverty alleviation which lead to societal sustainability are also important expectations of firms operating in EEs (London & Hart, 2004). These conditions present opportunities for business model and architectural innovations (Ray & Ray, 2011) to serve the unique needs of EE markets. From the above discussion, the differences between emerging and developed markets especially in terms of variations in market needs can be seen, since simply put "in the rich world, there are a few people who each spend a lot; in the developing world, there are a lot of people who each spend a little" (Govindarajan & Trimble, 2012).

Resource endowments in EEs

Access to research and educational institutions and the state of capital and labor markets are important factors that impact business activities (Bartholomew, 1997) by affecting access to resources necessary for business. Emerging economies face many constraints in the availability of and access to these conventional resources necessary for carrying out business. For firms in EEs, access to financial resources is often a major hurdle due to the underdevelopment of capital markets (Stiglitz, 2000). Another challenge is the availability of technological resources in the form of the presence of institutions supporting new technology development such as research organizations (governmental and non-governmental) and universities, as also skilled human capital such as research scientists and R&D technicians (Archibugi & Coco, 2004; 2005). This is also attributed to the overall lower levels of education in EEs in comparison to DEs. Also, since most EEs are behind the technology frontier they cannot access technology knowledge from other external sources such as related and supporting industries, competitors, and suppliers to the same extent as can DEs (Lundvall, Johnson, Anderson, & Dalum, 2002). This makes advancements in technology and the development of new innovations difficult. The challenges in accessing these input factors pose substantial hurdles to firm activities in EEs.

The scarcity of monetary resources in EEs translates into scarcity of monetary resources held by customers. With limited purchasing power, customers in emerging markets, unlike the ones in developed markets, do not demand high levels of performance brought about by continuous updation of technology; instead their emphasis is on decent performance at a low cost (Prahalad, 2005). This pushes the innovativeness of firms even further since it is not only important to make functional products, but also ones that are economically, socially, and environmentally sustainable (Hart & Christianson, 2002). One of the key advantages that EEs offer to firms are the low cost resources in comparison to DEs. Specifically with respect to R&D and innovation, the cost per square meter for setting up a biotech lab is a tenth of the cost of setting up a corresponding lab in the US (Kafouros, Buckley, Sharp, & Wang, 2008). Further, the salary of a scientific researcher In India is a tenth of the salary of a similarly skilled researcher in Sweden (Granstrand, Patel, & Pavitt, 1997).

This discussion highlights the number of constraints in emerging economies and unique characteristics that differentiate them from developed economies. These constraints present many hurdles to the development of new technologies for emerging economies. Thus the enormous business opportunities latent in EEs come with their share of complexities and challenges. Table 2.2 provides a summary of these unique characteristics of EEs and their impact on firm activities in EEs.

Table 2.2: Characteristics of EEs and implications for EE firms

Characteristics of Emerging Economies	Implications for EE Firm Activities
Institutional deficiencies (Peng et al., 2008; Young et al. 2008)	Regulatory interference leading to delays in operationalization
Dominance of social systems (Khanna & Palepu, 2007)	Challenge of overcoming opposition and influencing social opinion
High diversity in markets (Hoskisson et al., 2013)	Need for high level of customization of product and service offerings
Underdeveloped infrastructure (Peng et al., 2008)	Difficulty in mobilization of resources and accessing markets
Focus on societal impact (Govindarajan & Trimble, 2011)	Need to develop socially and environmentally sensitive product and service offerings
Scarcity of resources (Govindarajan & Trimble, 2011)	Markets' emphasis on frugality and price sensitivity

2.2 Literature on Economic Development of Emerging Economies

Economic development of EEs is a phenomenon that has generated much research interest over the years. Economic development to the extent that the productivity levels of developing countries converge with those of developed economies represents *economic convergence* by developing countries (Abramovitz, 1986). Drawing from this literature on economic convergence that "being backward in the level of productivity carries a potential for rapid advance" (Abramovitz, 1986: 386) it can be argued that as a result of being behind, emerging economies will grow at faster rates than developed economies until their growth rates converge.

Economic convergence

The phenomenon of convergence has been examined in the past in the context of the rise of the Asian Tigers namely Hong Kong, South Korea, Singapore, and Taiwan (Young, 1992, 1995; Easterly, 1995; Fukuda & Toya, 1995) and then in the context of the growth of ASEAN countries namely Indonesia, Malaysia, Phillipines, Thailand, and Singapore (Lim & McAleer, 2004) and in recent years the focus of examination has shifted to emerging economies such as Brazil, Russia, India and China. Much of this literature finds that the rate of convergence varies greatly from country to country. Some of the initial studies that focused on convergence between OECD countries and found positive convergence occurring (Baumol, 1992; Delong, 1988) with later research focusing on convergences by Asian countries and the lack of convergence in Africa. Barro & Sala I Martin (1992) examined convergence across 48 American states and found convergence in levels of per capita incomes. Barro (1991) examined growth across 84 countries and was unable to find significant explanations for the low economic growth of sub Saharan African countries. Baumol (1986) who focused on 72 different countries found that some of the poor countries of the world were the ones growing most slowly too. Overall these studies found that not every developing country was actively engaged in the convergence process. From amongst the ones that were actively trying to catch up, the rates of convergence varied greatly depending on various country level factors. These factors are discussed below.

Factors contributing to convergence

The notion of convergence has been used in order to explain the growth in industrial productivity wherein developed economies such as the US have been viewed as leaders with other countries being viewed as followers with the opportunity to catch up. The success or failure of the convergence process depends on numerous factors as well as players who are actively pushing this process forward.

One of the reasons for absence of such convergence has been identified as the lack of *social capability* (Abramovitz, 1986). Social capability facilities the diffusion of knowledge by providing conditions conducive for the development of labor markets, and macroeconomic conditions that encourage capital investment and demand. The presence of these social capabilities in a country will allow for convergence to take place. Social capability does however have a constraining impact on the opportunities for convergence in that the institutional systems and nature of organizations which evolve to give impetus to particular technologies may restrict adaptability and the ability to develop and employ more advanced technologies.

Physical and human capital are also key factors contributing to convergence (Romer, 1989; Lucas, 1988). Capital accumulation (either physical or human) plays an important role in determining the rate of convergence (Mankiw et al., 1992; Barro, 1991; Barro & Sala I Martin, 1992; Barro et al., 1995). While examining factors impacting economic growth Barro (1991) finds that growth rates are positively related to human capital and political stability negatively related to government consumption expenditure such as taxation and finds no relation to levels of public investment. Martin (1995) makes the diminishing returns to capital argument to explain the reasons for convergence. Bernard and Jones (1996) put forth the notion that convergence is not an automatic phenomenon and find in their examination of 14 OECD countries that service industries drive convergence more than manufacturing. Keefer and Knack (1997) argue that the ability of countries to achieve convergence is also determined by the institutional environment in the country. Convergence is also achieved through a reduction in the dispersion of income levels across countries which leads to a faster growth rate in developing countries compared to more advanced countries (Lee, Pesaran, & Smith, 1997; Young et al., 2008).Thus literature examining economic convergence does not view the backwardness of countries as representative of challenges, in fact the backwardness is what allows these countries to grow at faster rates than developed ones and catch up with them.

2.3 Literature on New Technology Development in EEs

In addition to the factors identified above, economic convergence is also achieved through technological progress. Developing countries can increase their industrial productivity and achieve convergence by expanding their innovative capabilities (Furman & Hayes, 2004). Developing countries begin the convergence process at much lower levels of productivity but over time they witness a rapid increase in their productivity and income levels due to accumulation of technological capabilities (Bell & Pavitt, 1997).

Prior literature has focused on two forms of convergence: technology driven and market driven convergence (Duysters & Hagedoorn, 1998; Lee & Lim, 2001). Technology driven convergence generally precedes market driven convergence since the market success of new products is contingent upon factors that determine the competitiveness of products in addition to their level of technological novelty.

EEs are typically late entrants in the global arena and as emerging innovators have significantly low innovative capacity when compared to advanced nations which are leading innovator countries (Kumar et al., 2013, Mathews, 2006). Thus, in order to understand the current phenomenon of new technology development in EEs it is important to review prior work that examines technological development in other contexts. The stream of literature on technological convergence examines the antecedents of technological progress and its outcomes i.e. its impact on economic development. Below is a discussion of the same.

Technological convergence

Technology is related to economic development and convergence in three different aspects viz. technological change, technological catch-up, and capital accumulation (Kumar & Russell, 2002). Technology change reflects shifts in the world production frontier, determined by new developments in the state-of-the-art of technology. Technology catch up reflects movements toward the technology frontier as countries adopt "best practice" technologies. The last aspect of capital accumulation deals with economic convergence discussed above.

According to seminal work in the area of convergence, technological progress is a crucial factor driving economic growth in backward countries (Gerschenkron, 1962; Rosenberg, 1982; Abramovitz, 1986). Foreign investment, innovation, and education have been identified as the reasons contributing to convergence (Amable, 1993). Prior research has found that countries have been able to achieve convergence by adapting and imitating the established technologies from advanced countries (Bae, 1997; Kim, 1980; Lee et al., 1988; Vernon, 1966). Baumol (1986) identifies 'innovation sharing' as a reason for convergence. Bernard & Jones (1996), speaking specifically to convergence of labor productivity, formally model the role of technology on convergence (they interpret the role of technology as the ability of countries to adopt leading technologies). Much of this older research - similar to Bernard & Jones (1996) - focuses on the adoption of existing technologies in advanced economies by developing economies.

Newer research also focuses on the indigenous development of new technology in addition to the adoption of already established technologies previously developed by DEs. For example, Madsen (2007) finds that spillovers of the knowledge of technologically sophisticated products as a result of international trade contribute to the development of new technologies domestically and consequently contribute to convergence.

In addition to spillovers and diffusion of technological knowledge, convergence also takes place through the internal development of new technological knowledge. Kristensen (1974) argues that development of the capability to leverage and utilize existing knowledge is a prerequisite to the ability to assimilate international knowledge spillovers for countries. On similar lines, Verspagen (1991) examines why some countries are able to catch up while others tend to fall behind and argues that poor countries will continue to stay behind unless they demonstrate initial learning capability which countries can then build upon to try to catch up to some extent. Total convergence however will occur only when countries can move beyond existing technologies and expand their innovative activities to the development of novel technologies.

Process of technological convergence

Literature focusing on differences in innovation capabilities argues that early innovators or countries at the forefront of technology face some disadvantages which can translate into advantages for latecomers trying to catch up, in that late comers will not repeat the mistakes made by the pioneers and hence not incur the high costs as the former (Ames & Rosenberg, 1963). In arguing so, they quote Kindelberger (1961) - "there may be a penalty in the early start, if institutions adapt themselves to a given technology, and if static patterns of capital replacement develop as habits."

However, many developing countries fail to completely catch up with advanced nations in spite of a growth spurt. This is because technological convergence is achieved by *leapfrogging* (Perez & Soete, 1988; Perez, 1988; Hobday, 1995; Lee & Lim, 2001) wherein countries do not simply follow the trajectories of growth of established countries but skip some stages or create their own path to bypass established technologies and catch up.

According to Lee and Lim (2001), there are three types of models adopted by developing countries for achieving technological convergence. First, in the more traditional model, countries use phase wise catch-up of *path following* wherein they follow existing, well established technologies and use the same trajectory of the development a technology as the forerunners. Alternatively, countries can engage in two types of leapfrogging – *stage skipping* where they may skip one or more stages in the technology trajectory followed by the forerunner to speed the catch-up process and *path creating* where the latecomers explore and create their own technology path. Further, the extent to which this process involves the use of the stage skipping or path creating strategies is dependent upon the initial technology capability of firms and their access to new knowledge (Mu & Lee, 2005).

Technology and Innovation in EEs

The phenomenon of innovation has been the subject of significant academic research. "Innovation is a process that begins with an idea, proceeds with the development of an invention, and results in the introduction of a new product, process or service to the marketplace" (Edwards

& Gordon, 1984: 1). Innovation is a complex phenomenon and is the result of a number of firm, industry, intra organizational and institutional influences (Ahuja, Lampert, & Tandon, 2008). Innovation is the introduction and application of new and improved ways of doing things (West, 1997; Anderson & King, 1993). This 'introduction and application' includes two elements – idea generation and implementation. It is not enough for firms to employ their creativity and generate new ideas, the implementation of innovative ideas is equally if not more important.

Innovation is viewed as an important source of competitive advantage (Grant, 1996; Porter 1990). "Innovative activity, which can be initiated by individuals or organizations, reflects a firm's entrepreneurial orientation" (Lumpkin & Dess, 1996; Naman & Slevin, 1993). The ever evolving global environment requires firms to stay abreast of the rapidly changing needs of markets and deliver innovative products in order to stay competitive. This requires that organizations actively pursue novelty and make improvements in their approach; and they do this by innovating in many ways – be it through technological innovation, organizational innovation, or business model innovation. Innovation is even more crucial in emerging economies since centrally developed, global solutions cannot meet the demands of the unique characteristics of EEs (as discussed in the previous sections). The focus of this dissertation is on the phenomenon of technological innovation in EEs.

Much of the prior literature examines innovation and technology development in the context of developed economies. In recent years, with increasing evidence of development of emerging countries, this phenomenon is now being examined in the context of EEs. This is important because despite the rapid growth of EEs, the conditions for R&D and the development and protection of new innovations in EEs are different from those in developed economies (Hoskisson et al., 2000). Innovation plays a critical role for firms operating in emerging economies as firms are increasingly adopting a *clean slate approach* in understanding these new markets and addressing their needs (Govindarajan & Trimble, 2012). This makes it an important phenomenon for examination.

Research examining innovation in EEs often focuses on low cost, architectural innovations (e.g. Govindarajan & Ramamurti, 2012; Ray & Ray 2011). Anderson, De Dreu, and Nijstad (2004) propose that the 'distress' generated by resource constraints acts as a trigger for innovation – the same seems to be evident in EEs. Despite this, there is evidence of increasing involvement in new technology development by EEs as seen by the levels of patenting by these countries.

Fig 2.7: Number of US patents filed by select EEs

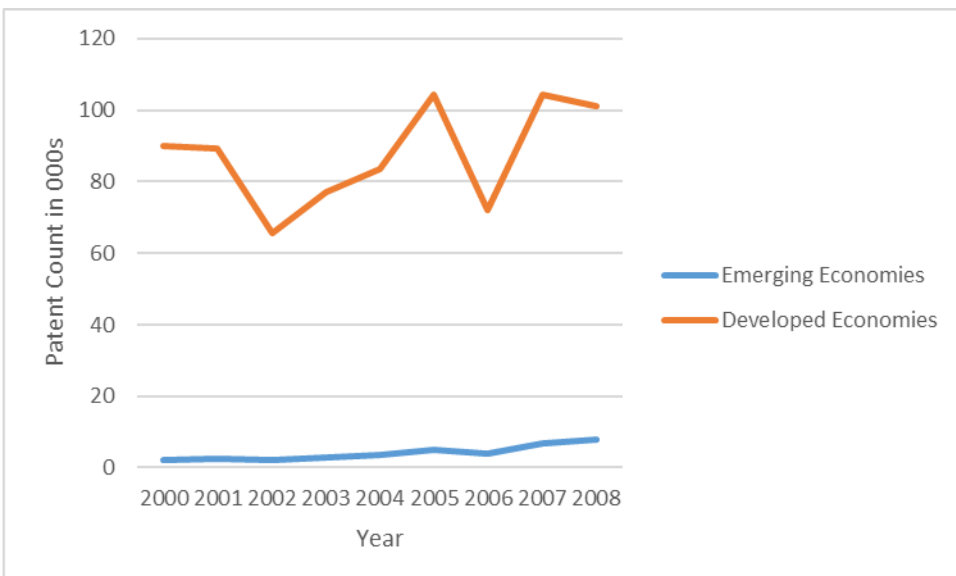
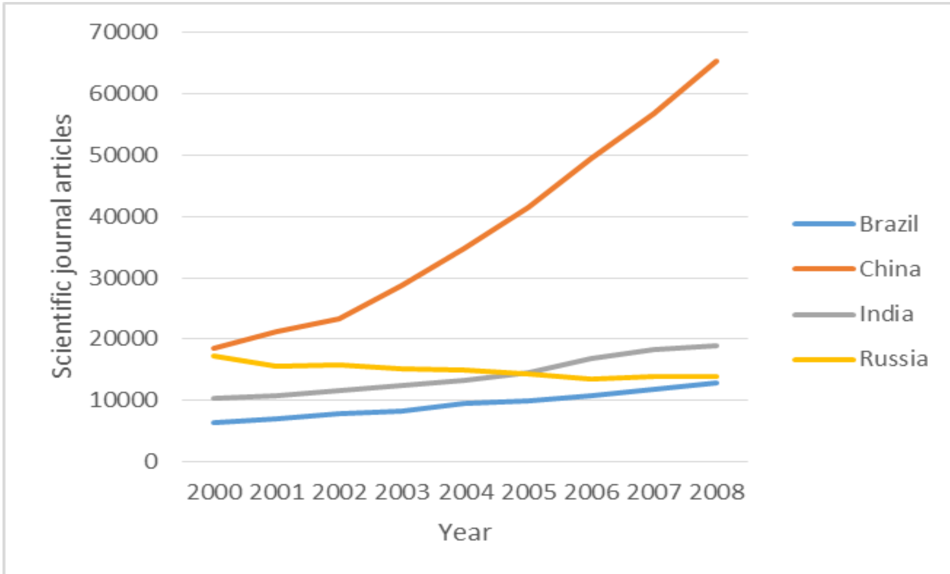


Figure 2.7 shows the number of US patents filed by the EEs in comparison to DEs from 2000 to 2008. Despite the overall levels of patenting by EEs being much lower than that of DEs, the data show a clear increasing trend suggesting that EEs are making significant investments in research and innovation activities and are successfully patenting their innovations for the international marketplace.

Fig 2.8: Number of scientific and technical journal articles from select EEs



Further, figure 2.8 shows the number of scientific and technical journal articles from the BRIC countries (data are from the WDI database) from 2000 to 2008. The data here refer to the scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. The rising trends here show the increasing involvement in new scientific knowledge creation. Figures 2.7 and 2.8 thus jointly show that EEs are demonstrating growth not just in the development of commercially viable new technologies (in the form of patents), but also in producing advancements in science and the global body of knowledge (through journal articles).

The testing, development and implementation of new technology innovations are resource intensive activities which require firms to have in place dedicated R&D facilities and production capabilities. However, many EE firms - on account of the resources constraints they face due to the inability to access resource markets and lack of availability of appropriate resources - may not have sufficient financial resources necessary for the research, development, and introduction of new technologies. Hence, idea generation may occur in a firm internally, but actual innovation may be thwarted due to resource constraints. This gives rise to the questions of understanding how do EEs overcome these constraints and develop new technologies, and what are the underlying factors that contribute to their development of successful innovations. Chapters 3 and 4 examine these questions in detail.

CHAPTER 3 NEW TECHNOLOGY DEVELOPMENT AT THE COUNTRY LEVEL

3.1 Introduction

Emerging economies are latecomers to the global marketplace (Bartlett & Ghoshal 2000; Ramamurti, 2012) and face many challenges in generating new technology innovations (Kothari, Kotabe, & Murphy, 2013; Kumar, Mudambi, & Gray, 2013). Despite this, new technology innovations as measured by patenting activities by emerging economies (EEs) have been on the rise (UNCTAD, 2013). This makes it important for researchers to investigate the antecedents of this phenomenon by examining the different economic and institutional factors that influence the conditions for the development and appropriation of new technology. Research examining new technology development at the country level has identified factors such as R&D expenditures and human capital in R&D (e.g., Teitel 1994; Furman, Porter & Stern, 2002) the strength of public research and higher education institutions (Mazzoleni & Nelson, 2007) and industrial clusters (Furman et al., 2002) in explaining the level of innovative output generated by different countries.

While prior research has focused on the level of patenting, there are significant gaps in our understanding of the nature of technologies that are patented. The development of new innovations varies depending upon the types of technologies that organizations choose to focus on (Danneels, 2002; Jansen et al., 2006; Subramaniam & Youndt, 2005). New innovations in mature, well understood technologies require a different set of capabilities than innovations in novel, emerging technologies (Zhou & Wu, 2010). Accordingly, the first research question I examine is whether there are any differences in the age of technologies that are patented by different countries. This study first examines differences in the level and nature of international patenting between DEs and EEs. To do this, I examine patents filed by 48 countries with the

United States Patent & Trademark Office (USPTO) from 2000 to 2008. I find significant differences in the level of patenting between DEs and EEs since the overall quantum of patenting by EEs is expected to by lower than that of DEs. Further, I find that there are significant differences in the age of technologies being patented by DEs and EEs in that the knowledge that EEs build on is significantly older than that used by DEs.

These findings from this first research question raise interesting questions regarding the reasons why these differences in the age of technologies being patented by different countries exist. Thus the second research question examines the underlying country level factors that influence the differences in the patenting activities. Here I build upon the institutional perspective that identifies factors such as educational and political institutions (Varsakelis, 2006), control of corruption, market-friendly policies, protection of property rights (Varsakelis, 2001; Tebaldi & Elmslie, 2013), and efficient equity markets (Hsu et al., 2014) that impact innovation. I argue that the differences in institutional conditions across countries leads to differences in patenting behavior of countries by influencing the incentives offered to the development and protection of intellectual property. In addition, I also hypothesize that the degree to which a country is connected to the global marketplace affects the ability to develop new technology by influencing the accessibility to knowledge and resources - both financial and human - necessary for the development of patentable innovations in different types of technologies.

To do this, I use the aforementioned data on international patenting activity of 48 countries with the USPTO. I also use data on measures of economic and institutional development of these countries over a period of 9 years from the World Development Indicators and the US Government Census database. I develop a panel dataset and use the Arellano–

Bover/Blundell–Bond linear dynamic panel-data estimation to test the hypotheses. The following sections describe the phenomenon of new technology development, the theoretical background, hypotheses, methodology, and findings from the study.

3.2 The Phenomenon

International patenting activity

In order to understand the phenomenon of new technology development in EEs, it is important to first examine the trends in patenting by EEs. The following set of figures pertain to total patenting activity by countries with the USPTO as represented by a count of patents. The patent count variable corresponds to the total number of focal patents filed in USPTO in a given year and approved in or before 2013 by inventors from a country other than US. Figure 3.1 shows the total number of US patents filed by the emerging and developed countries in the sample from 2000 to 2008. As we can see that the absolute number of patents by EEs are significantly lower than those by DEs. However, there is a clear growth trend in the patenting by EEs.

Fig 3.1: Count of US patents filed by EEs and DEs

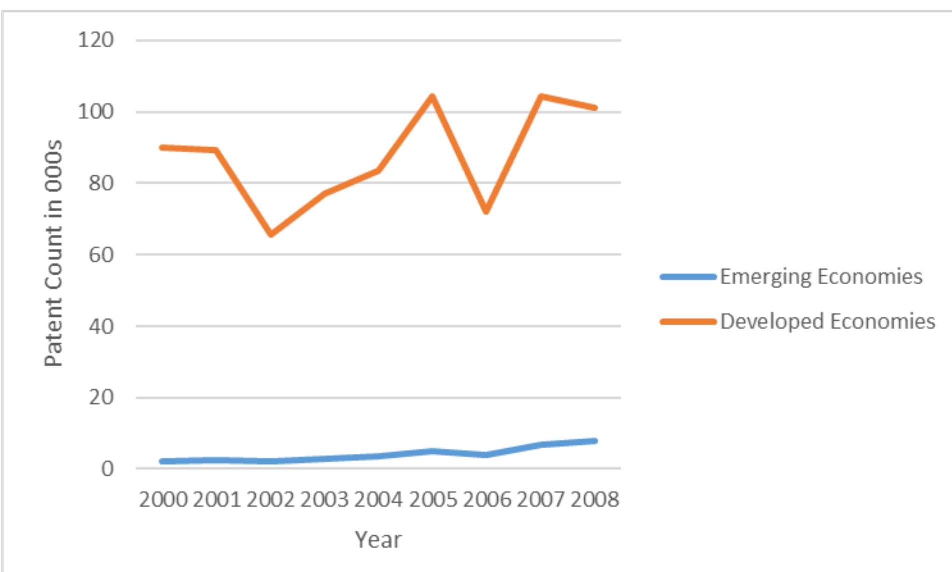
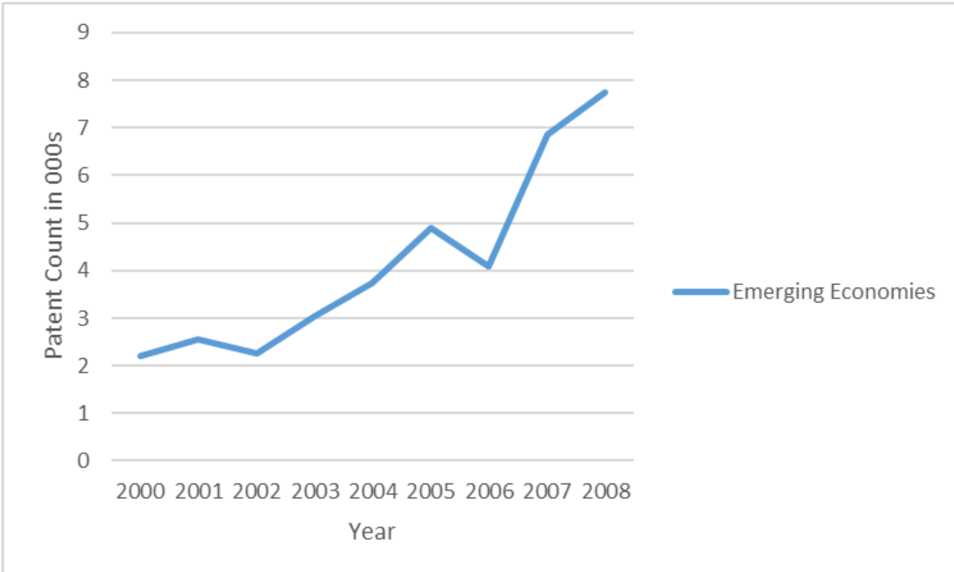


Figure 3.2 demonstrates this growing trend further. A graph of the total patenting by all emerging economies in the sample with the USPTO is reported here. Since 2000, the number of patents by EEs has dramatically increased.

Fig. 3.2: Count of US patents filed by emerging economies



This is an overall trend growth of all EEs over the years so next I examine the patenting of specific countries in the sample. Figures 3.3 and 3.4 contain information on the patenting activity of a few select countries thus help to understand the patenting behavior in detail. I separated the patenting by EEs and DEs into separate graphs since the absolute values of patent counts by DEs are still significantly higher than those of EEs, however the overall trends of EEs' activities are similar to the ones noted above. Figure 3.3 shows total patenting by the four BRIC countries of Brazil, Russia, India, and China. There seems to be a lot of variation in the counts of patents by these countries - with China showing highest absolute numbers and highest growth as well - but all countries show growth trends over the years (except Russia).

Fig 3.3: Count of US patents filed by four select EEs

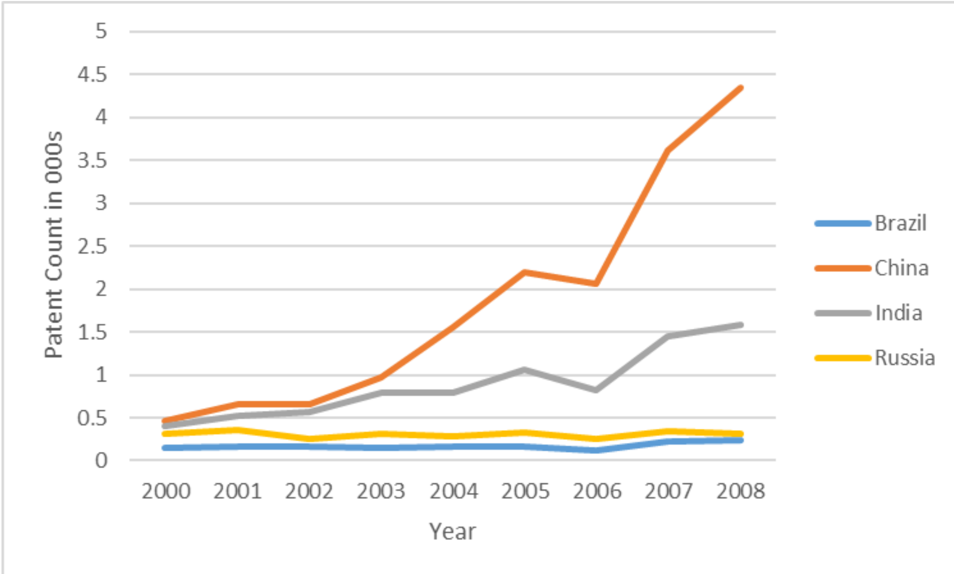
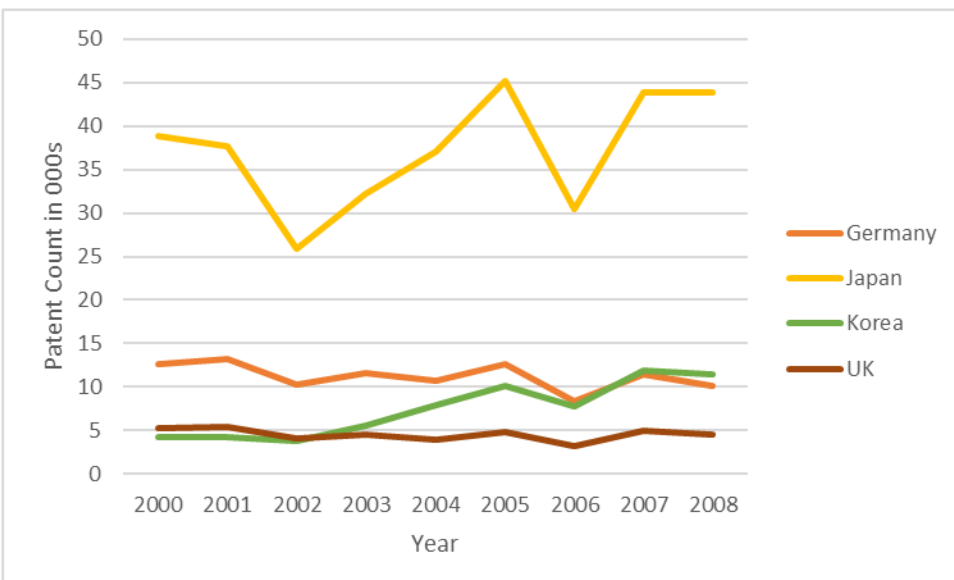


Figure 3.4 shows total patenting with the USPTO by four DEs namely Germany, Japan, Korea, and UK. Here again, there is variation in absolute counts of patents - with Japan having significantly higher absolute numbers than the other three countries; however the general patenting behavior across these four countries shows a downward trend over the years. These observations are in line with those from graph 3.1.

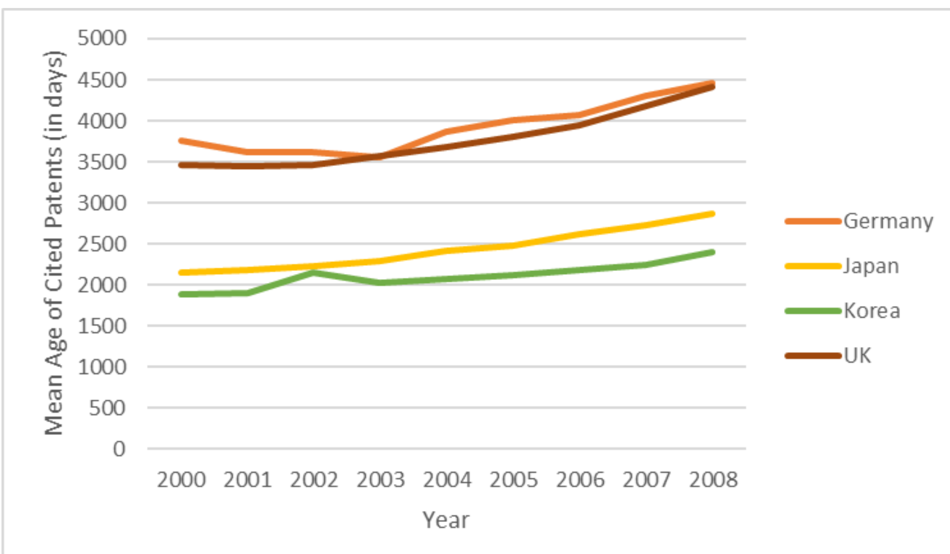
Fig 3.4: Count of US patents filed by four select DEs



Mean age of technology knowledge of patents

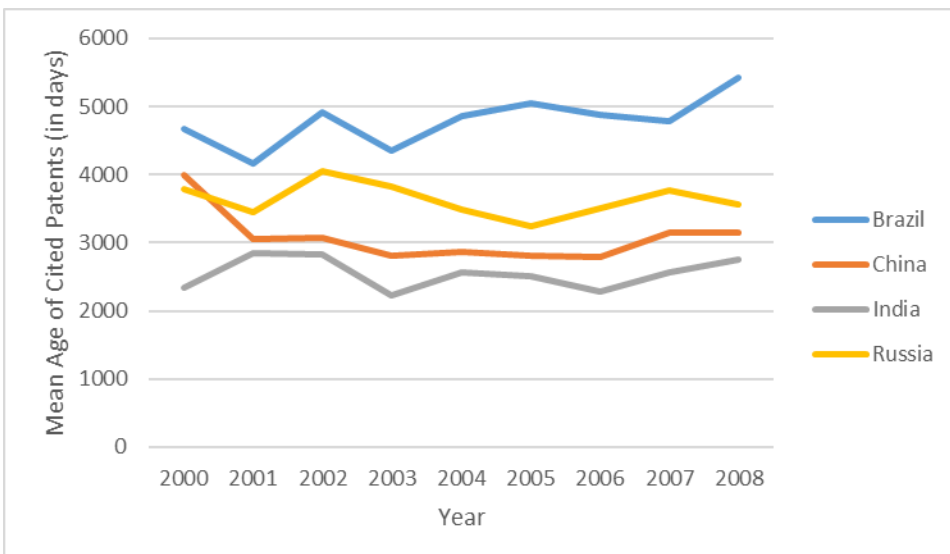
The variable mean age of knowledge refers to the novelty of technology knowledge that patents draw from. As a result this measure is correlated with the number of patents that are filed. The mean age of cited patents corresponds to the mean age (days) of patent citations associated with each focal patent, averaged for a given country and year. Figure 3.5 shows the mean age of cited patents of 4 DEs namely Germany, UK, Korea, and Japan. Here we see that Japan and Korea draw on more novel technologies in their innovations than do Germany and UK. Since Japan and Korea converged into developed economies significantly later than Germany and UK these differences in the age of cited knowledge suggests that the level and nature of country development may have an impact on technology innovation. Overall though there is an upward trend indicating a trend towards drawing on older technology fields by all DEs.

Fig 3.5: Mean age of knowledge for select DEs



Further, figure 3.6 shows the mean age of cited patents for four EEs namely Brazil, Russia, India, and China. Here we see that while India patents in the most novel technologies, China patents in relatively older technologies despite its absolute patent count being much higher than that of India. Brazil and Russia tend to patent in significantly older technologies – older than those in which the 4 advanced economies above tend to patent. Despite these differences in absolute numbers, the trends in the mean age of cited knowledge remain relatively stable across time for all EEs. Thus we can see that the growing trend of age in the case of DEs above is not replicated in the case of EEs. These interesting observations necessitate further examination which is detailed in the next section.

Fig 3.6: Mean age of knowledge for select EEs



3.3 Theoretical Background

New Technology Development and Technology Knowledge

The examination of the phenomenon of new technology development is important because technology innovation is a key source of competitive advantage (Porter, 2011). However, not all kinds of technology knowledge lends to equivalent features for competitiveness. Knowledge can be classified along different dimensions. Successful innovations depend on the ability to build on existing knowledge (Nonaka, 1994) and draw from external sources of knowledge (Cohn & Levinthal, 1990).

There are many ways to classify innovations, but one basic approach is the age of the technology that is embodied in the innovation. Specifically, this pertains to the novelty of the technology field (the degree to which a patent builds upon older or newer technological innovations). The theoretical perspective of technology lifecycle (Abernathy & Utterback, 1978) argues that technologies have a lifecycle which begins when they are emerging in nature and gradually move towards maturity. Emerging technologies are cutting edge technologies that are recent or new to an industry. Several emerging technologies may coexist in an industry, but over a period of time and with repeated adoption, a single technology gains supremacy and matures into the dominant technology (Abernathy & Utterback, 1978; Anderson & Tushman, 1990).

Emerging technologies tend to be riskier and less reliable (OConnor & Veryzer, 2001), and require greater resource commitments (Stringer, 2000) compared to mature technologies which have been prevalent in the industry for some time and are well understood by the industry players. Firms also face the risk of being locked out of the industry in case they are unable to adopt the dominant technology that emerges over time (Schilling, 1998). Since mature technologies are relatively well known firms have greater legitimacy with their stakeholders when engaging in this type of research (Ahuja & Lampert, 2001). Emerging technologies also require greater resources due to the higher levels of uncertainty. Given the high level of uncertainty there are fewer competitors for emerging technologies and the number of patent applications are lower. As a technology matures, the number of patent applications increase

(Haupt, Kloyer, & Lange, 2007) and the median age of the prior art increases (Nerkar, 2003, Sorensen & Stuart 2000).

Thus the use of both old and new knowledge offers benefits and costs to innovation and organizations that file for patents have to make decisions on the types of knowledge to access and build upon to develop new innovations. Accordingly, I classify technologies patented on the basis of novelty of the field of technological knowledge. For example, knowledge on steam engine technology is relatively well established since the technology was established a long time ago as against knowledge in nanotechnology which is a more novel field and hence the opportunities for technology innovation are ample but the novelty also makes it harder to develop successful innovations.

Technology Knowledge and Patenting

As discussed above new technology development is a source of competitive advantage. Patents allow organizations to protect the new technologies that they develop from imitation and thus allow them to gain rents from their research activities. Prior research that examines the phenomenon of new technology development studies the international patenting activities by developed country firms with patent offices in developing countries (Paci, Sassu, & Usai, 1997; Penrose, 1973). Since the development of technology innovations is the phenomenon of interest, the examination of international patenting activities is even more relevant. This is because the substantial R&D investments made for the development of high technology innovations necessitate the selling of these products to larger international markets so that firms that are carrying out R&D activities can generate adequate returns for their investments (Bruton & Rubanik, 2002; Bruton, Dess, & Janney, 2007). New technology development as measured through international patenting activity thus represents the generation of new technology knowledge since this knowledge is codified in the form of patents.

Patents provide incentives for research and development and the consequent development of new inventions. In the absence of patent protection, organizations would have no incentives to develop new technologies since they would be offered no system to protect the intellectual property developed through their investments and they would be unable to reap profits on their investments due to easy imitation by others once the innovation has been developed (Stack, 2011). In addition, the time limit on the IP protection in patents is also supposed to be a more effective form of knowledge dissemination and new innovation development since the patent allows the technology knowledge to be in the public domain (which would have otherwise been a trade secret for indefinite amount of time) and allows the use of this knowledge upon expiry of the patent for the development of new technologies. Thus patents are supposed to advance the science and technology frontier by encouraging innovation. Further, the availability of this knowledge in the public domain allows competitors to 'invent around' the existing patent (Kumar, 2002) which leads to a proliferation of many competing technologies that are available in the market and the rise of most efficient, dominant technologies is determined by market forces (Kim, 2002).

Patents provide legal protection to prevent others from using an invention and hence patent application also reflects the incentives for not just the development of new innovations but also the effectiveness of the legal system that grants these rights in the protection of these rights. Thus patent applications become especially important in the context of emerging economies where the quality of legal systems is generally lower than that in DEs.

The value of a patent is determined through a comparison of the economic returns generated by the innovation with patent protection (including the costs of patent application process) versus the returns from the innovation without patent protection (Lanjouw & Lerner, 2000). Accordingly, the application of a patent for the protection of the underlying invention is a strategic decision made by the patent assignee. This decision is made based on the evaluation that the patent will generate returns over and above the costs of application and better returns than if the innovation had been protected as a secret (Lanjouw, 1993). This value determines application decisions made by assignees and thus patent data provides information on the value of not just the invention but the rights to the invention (Lanjouw & Lerner, 2000). Thus the source of the ownership of a patent is an important indicator that the owner (assignee) can draw economic value from the patent.

Applicants for the patents may suggest the technical classifications applicable to their application, but patent examiners who work with the USPTO are the ultimate arbiters of class assignments. In addition, applications are filed through experienced patent attorneys, who make these suggestions for the appropriate classes for a given patent. Hence, the use of such specialists (i.e., patent attorneys and examiners), in addition to the thorough examination that each patent is subject to before being granted minimizes risks of misclassification of patents and ensures absence of errors due to misclassification (Sampson, 2007).

Patents provide detailed, publicly available information which is fairly standardized and available over long periods of time. This detailed information corresponds to first the characteristic of the inventions such as information on the new technologies developed including the classes of knowledge that the patent draws from, the age of existing knowledge that it draws from (in the form of cited patents), and the inventive claims it makes, all of this in addition to the technical information captured in it. In addition, patents also provide detailed information about the origins of the invention such as the organizations that own the innovations (assignees), the specific inventors who developed the inventions, and their locations. Research streams dedicated to the forecasting of new technologies use information from patents to indicate the state of current technologies and forecast the evolution of technologies (for eg. Chang, Wu, & Leu, 2010; Daim, Rueda, Martin, & Gerdsri, 2006; Mogee, 1991).

Despite the rich, detailed information available within patent data, the importance of the innovations that are protected by each patent vary widely and hence patent counts are an imperfect measure of innovation (Lanjouw & Mody, 2006). Hence it is important to use additional information about patents in addition to their counts to understand innovation better. Hence I construct variables that further refine the nature of technology being patented and develop measures of the novelty and diversity of the technology knowledge encoded in the patents.

3.4 Hypothesis Development

Comparison of DEs and EEs and international patenting

EEs face many challenges in being able to bring about technology development that arise from weaknesses in legal systems and intellectual property rights regimes (Peng, Wang, & Jian, 2008), underdeveloped physical and social infrastructure (Wright, Filatotchev, Hoskisson, & Peng, 2005), absence of social capabilities and consequently lack of technological opportunities (Abramovitz, 1986), and weak institutional systems in general (Peng, 2003). This makes the protection of intellectual property difficult which subsequently disincentivizes not only the protection of new technology innovations through patenting but also their development. Thus, a key challenge for EEs is being able to overcome the disadvantages as a result of lack of institutional development. DEs on the other hand do not face such challenges due to the presence of strong institutional systems.

Further, the development of innovations and their subsequent patenting is a resource intensive activity due to the need for monetary and knowledge resources to be able to generate technological advancements that are novel enough to be patented and will generate economic return over and above the investments made in their development. Since most EEs face constraints in the amount of financial resources available as also in accessing financial resources due to underdeveloped capital markets, their ability to develop such patentable innovations is significantly diminished in comparison to DEs. Accordingly, I hypothesize,

Hypothesis 1a: Other things being equal, there are significant differences in the level of international patenting activity by EEs versus DEs in that the level of patenting by EEs is less than that of DEs.

Innovation in nascent technologies is a risky activity with significant outcome uncertainty. DEs possess the financial and human resources required to take on this risky activity and make substantial investments that are necessary for innovation in nascent technologies (Hoskisson et al., 2012). DEs face high competition as a result of operating on the technology frontier and hence need invest in nascent technologies research which have high risks but also higher payoffs in order to maintain competitive advantage. DE firms are more likely to possess the R&D capabilities that are required to successfully generate innovations in novel, unexplored technologies. Engaging in research in nascent technologies can lead to greater possibility of creating a breakthrough innovation (Ahuja & Lampert, 2001). Since nascent technologies are early in their lifecycle, there is greater potential for generating successful innovations before competitors and gaining first mover advantages. Firms from DEs also operate closer to the technology frontier and can gain technology knowledge from geographical proximity to their competitors within their home markets where such emerging technologies are being developed by other firms as well (Fu, Pietrobelli, & Suete, 2011). In addition, they can also benefit from colocation in clusters and networks of innovation with related and supporting industries (Mudambi, 2008).

Given the high level of uncertainty and resources involved in nascent technologies related research, emerging economies, with their limited resource endowments, are less likely to invest in these technologies. They are more likely to invest in mature technologies which are well established and have credibility with the end users. EEs are likely to have greater access to mature technologies than to nascent technologies since products based upon mature technologies are available for sale in EEs, and allow for opportunities for EE firms to reverse engineer and learn about these technologies. Also, DE firms may be less concerned with technology leakage in mature technologies, and are more likely to partner with rival EE firms - even going so far as trading access to the mature technology in exchange for market access. Further, centralized investments by EE governments focus on market stimulating technologies (Lall & Teubal, 1998). Accordingly, I hypothesize,

Hypothesis 1b: Other things being equal, there are significant differences in the age of technology knowledge that EEs and DEs build upon while developing international patents in that the age of knowledge patented by EEs is older than that of DEs.

Factors influencing differences in the extent of international patenting

Literature that examines economic convergence has identified various factors that lead to differences in economic development between countries. Some researchers find that physical and human capital are key factors contributing to convergence (Romer, 1989; Lucas, 1988). Capital accumulation (either physical or human) plays an important role in determining the rate of convergence (Mankiw et al. 1992; Barro, 1991; Barro & Sala I Martin, 1992; Barro et al., 1995). While examining factors impacting economic growth Barro (1991) finds that growth rates are positively related to political stability. Bernard and Jones (1996) find in their examination of 14 OECD countries that service industries drive convergence more than manufacturing. Keefer and Knack (1998) argue that economic development is determined by the institutional environment in the country.

On the whole, economic development at the country level, denotes an availability of the input factors vital for innovation such as the resources for making investments in R&D. This includes both capital resources (Teitel 1994; Furman, Porter, & Stern, 2002) as well as human resources in the form of skilled human capital such as scientists and engineers (Tebaldi & Elmslie, 2008). The development of capital markets allows firms to raise capital vital for the research and development involved in new technology innovations (Hsu, Tian, & Xu, 2014). Prior research has also identified inflows of foreign direct investment as an important determinant of the availability of resources and spillovers of knowledge necessary for new technology development (Kinoshita, 2004).

A country's international trade environment also has a positive impact on its technological progress (Grossman & Helpman, 1994). Trade has an effect on international technology transfer through knowledge spillovers thus promoting innovation (Saggi, 2002). A country's trade linkages with other countries also represent its connectedness with these countries. Prior research has examined the relationship between a country's global connectedness and its innovation (Samant, Hatfield, Seth, & Thakur-Wernz, 2016). A country's global connectedness can be measured by its level of international trade (e.g. Ghemawat & Altman, 2011). Consequently, the higher the level of international trade carried out by a country, the more globally connected it can be said to be. A country's level of global connectedness will thus have a positive relation with its innovation. Further, since the international patenting activities of firms with the US demonstrate the economic value inherent in the innovations, these international patents are representative of significant new technological development. Accordingly, I hypothesize,

Hypothesis 2a: Other things equal, the level of international patenting activity by a country is positively associated with its level of global connectedness.

The state of the legal system of an economy determines the transaction costs to firms (Coase, 1937) in that weaker legal systems present higher transaction costs. EEs in general do not show the presence of exhaustive regulations with respect to patent laws and intellectual property rights (Peng, Wang, & Jiang, 2008) which might reduce the barriers to imitation significantly and thus make innovation an unfavorable strategic choice. Enforcement of contracts and resolution of disputes is more difficult in emerging markets, as also EEs are generally apathetic to intellectual property rights protection, and are tolerant towards counterfeiting, fake goods, and piracy, and other forms of IP rights infringements (Wang, 2011).This poses significant challenges for innovating firms which have very few ways of safeguarding their proprietary knowledge which can potentially give them a competitive advantage in the market (Grant, 1996; Zhao, 2006).

With respect to the institutional environment in EEs, Khanna and Palepu (1997) suggest that there is a high degree of governmental intervention in firms' activities, and the unpredictability of government policies and bureaucracy makes it difficult for firms to navigate operations. A contradictory perspective is offered by Govindarajan and Trimble (2012) who are of the opinion that since the regulatory systems in EEs are less developed, they present fewer delays and lesser friction when companies bring innovative solutions to the market. Weak institutional systems lead to higher transaction costs that reduce efficiency of firms (North, 1991). Weaknesses in the political and legal systems present challenges to the innovativeness of firms. Changes in the political conditions in EEs may lead to sudden, unpredictable public policy decisions which can seriously impair the long term strategies, and investments of firms.

The institutional development of a country plays an important role in the development and appropriation of innovations. Institutions support not only the development of innovations by allowing firms to access resources required for the R&D for new technology development, but also incentivize the appropriation of rents from the commercialization of these innovations by protecting the intellectual property embodied in these innovations. Strong intellectual property regimes in the form of sound legal systems, patent protection agencies, and regulatory quality of countries are positively associated with the level of innovations as a result. Specifically, national innovation systems such as public research institutions (Mazzoleni & Nelson, 2007), industrial clusters (Furman et al., 2002), and educational institutions (Varsakelis, 2006) support new technology development. Further, general institutional development through control of corruption, market-friendly policies, protection of property rights, and effective judiciary systems (e.g. Varsakelis, 2001; Tebaldi & Elmslie, 2013) promotes the development and protection of innovations. Accordingly, I hypothesize,

Hypothesis 2b: Other things equal, the level of international patenting activity by a country is positively associated with its level of institutional development.

Factors influencing differences in the age of technologies developed

Prior research suggests that engaging in innovations in novel technologies requires more financial and human resources and extensive research process knowledge (Stringer, 2000). The higher risk associated with nascent technology research also necessitates the availability of financial resources (O'connor & Veryzer, 2001). Country governments play an important role by channeling resources for investments in R&D as well as by developing overall human and physical capital that is conducive to innovative activity. Prior research has found that advanced economies produce and export more technologically sophisticated products (Grossman & Helpman, 1994). Thus economic development allows for the availability of financial and human resources necessary for investments in nascent technology development.

Literature from the national innovation system (NIS) perspective examines the roles of governments, firms, financial organizations, public research labs and universities (Guennif & Ramani, 2012; Patel & Pavitt, 1994). Country governments play an important role in developing NIS and can thus influence the nature of new technology development. Prior research shows that emerging economy governments encourage and support investments in technology development (Keefer & Knack, 1997; Lall & Teubal, 1998) and has emphasized the importance of institutional investments by governments through openness to FDI and FPI (Balasubramanyam et.al. 1996; Frantzen, 2000), promotion of research in educational institutions (Mazzoleni & Nelson, 2007), and development of skilled human capital (Barro & Sala-i-Martin, 1995) as mechanisms for new technology development. However, governmental attention and support tends to be focused on specific industries and technologies as demonstrated by the efforts of many countries in developing national champions (Goldstein, 2002) or stimulating specific industries (Hung & Chu, 2006) and country policies often lead to uneven development across different sectors (Gorodnichenko & Schnitzer, 2013). Despite this, overall global connectedness leads to more spillovers of novel knowledge and will consequently lead to innovations in more novel technologies.

Global connectedness

Prior research has identified the link between international trade and economic development (Vernon, 1966; Yamazawa, 1990). High technology trade and the associated economic growth has a positive relation with the level of innovation in a country (Schneider, 2004). A country's trade linkages with other countries also represent its connectedness with these countries. A country's global connectedness can be measured by its level of international trade (e.g. Ghemawat & Altman, 2011). Consequently, the higher the level of international trade carried out by a country, the more globally connected it can be said to be. A country's level of global connectedness has a positive relation with its level of international innovation (Samant et al., 2016).

This connectedness to international markets provides access to best practices prevalent in foreign countries and access to sophisticated customers in international markets. It also provides access to new resources that are unavailable domestically, specifically cutting edge foreign technologies (Schneider, 2005). Thus global connectedness provides *opportunities for innovation* in novel technologies that would otherwise have been unavailable. In this way global connectedness incentivizes patenting in novel technologies. Accordingly, I hypothesize,

> *Hypothesis 3a: Other things equal, a country's emphasis on international patenting activity involving nascent technologies is positively associated with its level of global connectedness.*

Institutional development

The quality of institutions in a country (such as legal reform, IP regimes, and trade liberalization) is an important factor impacting new technology development (Bevan, Estrin, & Meyer, 2004; Shinkle & McCann, 2013; Tihanyi & Roath, 2002). Technology innovations may first begin through the adaptation and imitation of established technologies from advanced countries (Mahmood & Rufin, 2005). The ability to adopt leading technologies has been identified as an important predictor of new technology development (Amable, 2000). This can be primarily achieved through spillovers of the knowledge of technologically sophisticated products from other countries. In addition, many innovations are also based on low cost manufacturing and process improvements to provide low cost products (Govindarajan & Trimble, 2012; Ramamurti & Singh, 2009).

Improvement in intellectual property rights and other institutions leads to a shift towards active engagement in technology development (Lee, 2013). The activities that firms engage in in order to develop technological capabilities evolve from duplicative imitation to creative imitation, and ultimately to novel innovation (Kim, 1997). An initial learning capability to leverage and utilize existing knowledge is prerequisite to the ability to assimilate international knowledge spillovers (Fagerberg & Verspagen, 2002; Li, 2011). Spillovers and diffusion of existing technological knowledge are vital for the development of innovations but the presence of sound institutional systems is more important for the protection of these innovations.

The absence of sound institutional systems provides *constraints for innovation*. In the absence of strong institutions any novel technologies that firms may develop will not be protected and will stand the risk of being imitated. This will disincentivize firms from making the significant R&D investments that are necessary for the development of such innovations.

Thus the development of institutional systems in a country is crucial for not only the protection but also investments in innovation. Sound institutions will incentivize innovations in nascent technologies. Accordingly, I hypothesize,

Hypothesis 3b: Other things equal, a country's emphasis on international patenting activity involving nascent technologies is positively associated with its level of institutional development.

3.5 Methodology

Data

For empirical analysis I use a panel data set of 8 years from 2000 to 2008 covering 33 developed and 24 emerging countries. The hypotheses are empirically tested using data on patenting activity by these countries as also information on other country level independent variables that influence patenting. For this, I have developed a dataset of all patents and their relevant details filed with the United States Patent Office (USPTO) from 2000 until 2008. Country-level data from the World Development Indicators (WDI) database by the World Bank and the UNESCO Institute of Statistics (UIS) database by UNESCO are collected as measures of the independent variables and other control variables.

Prior research on technological innovation uses patents as measures of innovation (Acs, Anselin, & Varga, 2002; Criscuolo, Narula, & Verspagen, 2005). Patents application is a well-established measure of new innovations (Griliches, 1990). Since there is a time gap between the time of application of patents and the granting of patents as a result of procedural issues, hence the use of patent applications is an appropriate measure of technological activity. Patents have been used as a measure of innovation in previous research, however simple patent counts do not offer depth of understanding about the knowledge embedded in the patent such as the quality of the patent and the scope and importance of the knowledge within (Tratjenberg, 1990). Particularly since the focus of this examination is on the type of technology that has been encoded in the patent, I extract detailed information within each patent to calculate the age of knowledge that each patent cites.

I select the US patent data for several reasons. First, this allows a consistent definition of innovation across firms and countries. Second, patenting with USPTO demonstrates the value and importance of innovations - since I am interested in international competitiveness, holding a US patent in a competitive, globalized world is an indicator of catch up. Third, the US patent database has been used by previous researchers to develop key measures of constructs to identify the nature of technology that the patent pertains to (Abrams, 2013; Arts, Appio, & Van Looy, 2013). Despite critiques about the use of patents - since all innovations might not be patented due to the varying economic impact of patents - in this case they are an appropriate measure of new technology developments which are likely to be patented.

Sample selection

The sample of countries I study in this paper was developed through a two-step process. The first step was to identify the countries that would be included in the study and the next step was to categorize the selected countries into developed and emerging economies. Since the study examines international patenting activity of countries I wanted to include only countries that showed some significant patenting with the USPTO and eliminate countries that had patented sporadically. So I only included countries that had more than 200 patents with the USPTO from 2000 to 2008 and did not include countries which had fewer than 200 patents. This yielded a total of 48 countries.

The next step was classifying the countries into developed and emerging economies. Table 3.1 details the names of countries and their classification. Of the 214 countries of the world identified by World Bank, 69 countries were classified as high income, 40 as low income, 56 as lower middle income, and 48 as upper middle income countries. Since I wanted to categorize countries into two separate classifications I used the International Monetary Fund's World Economic Outlook Report classification to classify the 48 countries as emerging or developed using a 0 1 code (0=emerging, 1=developed).

Table 3.1: List of countries included in the sample

Developed economies in samples	Emerging economies in sample
Australia	Argentina
Austria	Barbados
Belgium	Brazil
Bermuda	Bulgaria
Canada	Chile
Czech Republic	China
Denmark	Hong Kong (DE since 1997)
Finland	Hungary
France	India
Germany	Israel (DE since 1999)
Greece	South Korea (DE since 1997)
Iceland	Malaysia
Ireland	Mexico
Italy	Poland
Japan	Romania
Liechtenstein	Russia
Luxembourg	Saudi Arabia
Netherlands	Singapore (DE since 1997)
New Zealand	Slovenia (DE since 2007)
Norway	South Africa
Portugal	Thailand
Spain	Turkey
Sweden	Ukraine
Switzerland	
UK	

I coded the countries they identify as advanced economies as developed economies (DEs) and the ones they identify as emerging and developing economies as emerging economies (EEs). This yielded a total of 18 emerging and 29 developed economies over the entire time period from 2000 to 2008. Countries transition from emerging to developed over time. In this case, Slovenia transitioned in 2007 and is assigned the dummy code accordingly.

Measures

Patents One of the key independent variables is the level of international patenting (in this case US patents) by a given country. This variable is measured as the count of total patents filed by assignees from a country for a given year. Information on this variable was collected by downloading all patents filed with the USPTO from the USPTO website. Prior research that examines the phenomenon of new technology development studies the international patenting activities by developed country firms with patent offices in developing countries (Paci, Sassu, & Usai, 1997; Penrose, 1973). Since the development of technology innovations is the phenomenon of interest, the examination of international patenting activities is even more relevant. This is because the substantial R&D investments made for the development of high technology innovations necessitate the selling of these products to larger international markets so that firms that are carrying out R&D activities can generate adequate returns for their investments (Bruton & Rubanik, 2002; Bruton, Dess, & Janney, 2007). New technology development as measured through international patenting activity thus represents the generation of new technology knowledge since this knowledge is codified in the form of patents.

I recognize that not all patentable innovations may actually be patented. The process of application and approval of a patent is costly and time consuming. Thus it may be very expensive for the already resource constrained firms from EEs to invest the resources necessary for patent application and this may discourage some EE firms from filing for patents. However, since I only use USPTO patents for the empirical analysis, this implies that only the patents that are perceived to provide some international competitive advantage to firms are included in the sample. Since I assume that firms have made a decision on the application of a patent after careful analysis of the costs and benefits of the application process, they would only have applied for patents provided they represent significant benefits for the firm in the future.

Further, patents make some of the technology knowledge available in the public domain. Firms may not want to risk making this knowledge available and may prefer to maintain their knowledge as a secret. This may be even more applicable in the context of EEs given that the legal systems in EEs are not as strong as the ones in DEs. Thus the implementation of the protection of IP through patents may be difficult and arbitrations over patent infringement may be expensive and time consuming. Here too, the use of UPSTO patents implies that the applicants perceive value of this technology in international markets and hence choose to patent their technological developments with the USPTO.

In addition. I recognize that not all innovations may be patentable, especially in the case of EE markets, many innovations are geared towards cost based innovations or business model innovations. The focus of examination of this study is new technology based innovation. Since the USPTO is considered to be one of the important patent granting organizations worldwide and American markets value technologically sophisticated products, the patents granted by this organization naturally must be high quality patents that have been approved after a rigorous examination process. Thus the patents included in the sample represent cutting edge technology development.

Mean age of knowledge is the key dependent variable of examination. This variable measures the age of the knowledge of patents from a country for a given year. This is done by using information on the age of citations that the focal patents in the sample (filed by the assignees from a given country) cite as their source of knowledge. To develop this measure, I computed the mean age of all the patents that each focal patent cites. This age is calculated as the difference between the year of the filing of the focal patent and the year of grant of the cited patent. The year of filing of the focal patent is indicative of the time that the knowledge contained in the focal patent was first generated. The year of grant of the cited patent is indicative of the time that the knowledge contained in the cited patent was verified as novel by the patenting office and was made available for use to others. Thus the number of years that have passed between the grant of the cited patents and the filing of the focal patent is the total age of knowledge that each patent cites. The mean age for all patents granted to a country for a given year is then computed to generate the age of the knowledge portfolio at a country year level. *Appendix 1 details the development of this measure.*

Global connectedness This variable measures the level of global connectedness of a country. Prior research has measured countries' global connectedness by measuring their level of international trade (e.g. Ghemawat & Altman, 2011; Samant et al., 2016). Accordingly, I collected information on the imports and exports from the countries in the sample to the US in (millions of US dollars) from the Export Import Bank of the United States (EXIM) website. Some prior research studying the impact of trade on country development has argued that exports play a role in stimulating economic growth (Blumenthal, 1972). There is other research that argues that exports merely reflect favorable domestic conditions (Amsden, 1991) and may be a result of increased productivity and not a cause of it (Bernard & Jensen, 1999; Rodrik, 1995).

Instead, imports of capital goods and intermediate goods have a positive impact on domestic productivity by supplying inputs that would have been otherwise unavailable (Lawrence & Weinstein, 2001; Rodrik, 1999). Importing these inputs that are absent at home can then allow emerging economies to develop innovations in novel technologies. Further, prior research examining global connectedness has also utilized the level of imports as a measure for this construct (Samant et al., 2016). Accordingly, I proxy the level of a country's global connectedness using information on the level of imports.

Institutional development This variable measures the level of institutional development of a given country for a given year. Data on this variable was extracted from an indicator of the regulatory quality of countries from the World Governance Indicators database. Regulatory quality captures the perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development (WGI, 2015).

Control variables

I control for differences in overall productivity between countries by controlling for *per capita GDP* across countries using data from the WDI database. This is important since different EEs show varying levels of productivity and economic development (Hoskisson et al., 2012) which can impact technology development. The development of human capital is an important factor impacting technology development since skilled labor and R&D personnel can promote growth in new technology development (Barro & Sala-i-Martin, 1995). Hence, I also control for differences in human capital development across countries by measuring the *R&D expenditure* in million USD in a given country. This information was collected from the WDI database. Since entrepreneurship is considered to be a catalyst for new technology development (Wong, Ho, & Autio, 2005), I control for the number of *new LLCs* incorporated in each country each year. As discussed in sections above, FDI is a source of significant knowledge spillovers that can impact technology development in terms of volume of innovations as also the type of technologies (Kinoshita, 2000; Fu, 2008). Hence, I control for the total values of *FDI inflows* in million USD to different countries using information from the WDI database to identify the impact of technological diffusion through international business on countries. I also include *population* as measured in million people to control for differences in size.

Individual countries are categorized into “emerging” and “developed” based upon the International Monetary Fund’s World Economic Outlook Report April, 2012. The indicator variable is coded as a “1” if the country is a developed country and “0” if it is an emerging country. I noted that a few countries that were “emerging” in the past, transitioned into “developed” over time and so the country category classification is dynamic over the years.

Model

Since the focus of hypotheses 1A and 1B is on differences between DEs and EEs I conduct a two sample t test by grouping countries into emerging and developed groups.

Traditionally most panel data analysis involves the use of static estimation models such as fixed effects or random effects. However, the endogeneity issues associated with the use of these models are alleviated by the use of dynamic panel data models such as the Arellano Bond model (xtabond in STATA). This model involves the use of lagged values of the dependent variable as instruments for the dependent variable and uses a Generalized Method of Moments estimation using these variables. Further, the use of the Arellano–Bover/Blundell–Bond correction takes into account the presence of autocorrelated errors and hence resolves the problem of autocorrelation. *Appendix 2 details the rationale and use of this methodology.*

Accordingly, I test hypotheses 2 and 3 using Arellano–Bover/Blundell–Bond linear dynamic panel-data estimation (xtdpdsys in STATA) where the key dependent variables are the count of patents and the mean age of cited knowledge of patents filed at the country-year level. The econometric model I use for hypotheses 2 and 3 is as follows:

$Y_{it} = \beta_1 X_{it} + \beta_2 W_{it} + \alpha_i + €_{it}$

where Y is the dependent variable where i = country and t = time

$\alpha_{i\ (i=1....n)}$ is the unknown intercept for each country

X_{1it} represent exogenous regressors

W_{it} represent lagged dependent variables and endogenous regressors

$€_{it}$ is the error term

3.6 Results

Summary statistics

Table 3.2 shows the summary statistics for the data. The variable mean age of knowledge measures the novelty of technology knowledge that patents draw from at the country year level. This variable is negatively correlated with the number of patents filed by a country.

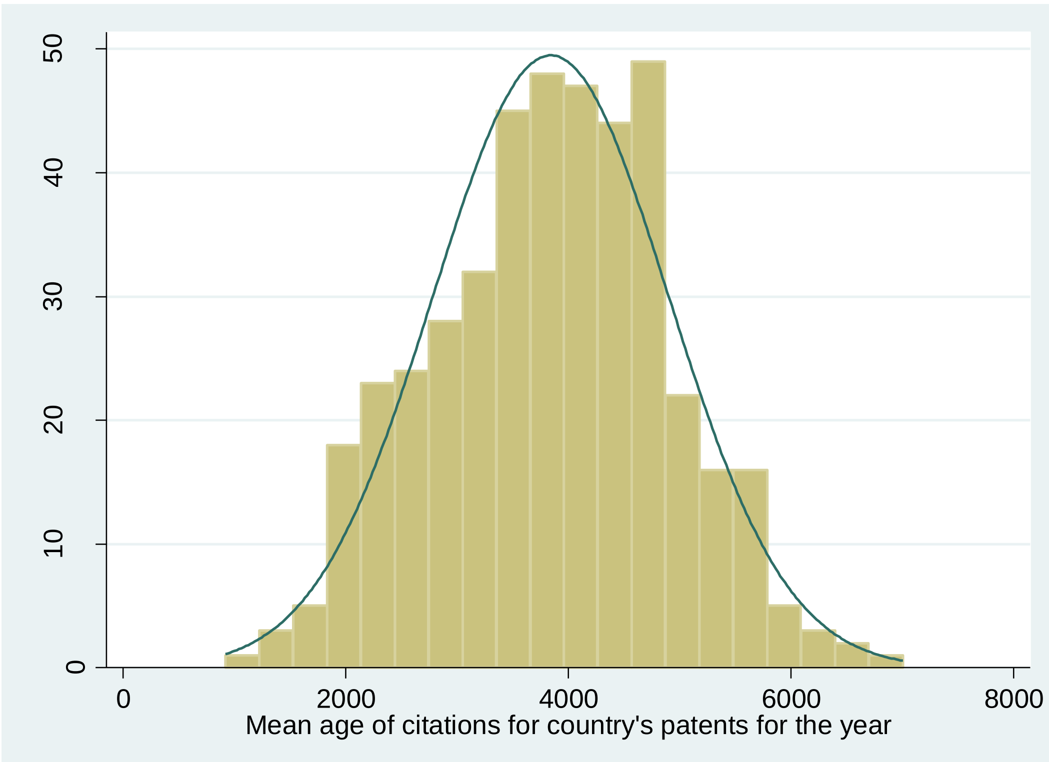
Table 3.2: Summary statistics

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
Patents	5.71	1.91	1.00									
Age of Knowledge	3843.03	1059.76	-0.33	1.00								
Imports	0.15	0.31	0.41	0.00	1.00							
Regulatory Quality	0.99	0.71	0.34	-0.09	0.07	1.00						
GDP	0.26	0.22	0.27	-0.01	0.00	0.66	1.00					
Number of LLCs	45.41	63.39	0.30	-0.01	0.10	0.10	-0.01	1.00				
FDI Inflows	4.93	9.90	-0.05	-0.04	-0.04	0.21	0.17	-0.10	1.00			
R&D Expenditure	1.43	0.93	0.65	-0.34	0.12	0.48	0.54	-0.09	0.00	1.00		
Population	0.08	0.23	0.18	-0.18	0.08	-0.45	-0.29	0.05	-0.08	-0.14	1.00	
Country Category*	0.59	0.49	0.55	-0.14	0.11	0.73	0.72	0.10	0.08	0.62	-0.30	1.00

*Country Category 1=DE, 0=EE

Mean age of knowledge: The interesting country level trends discussed in the previous section necessitate a detailed examination of the variable age of knowledge and what the variable represents. Figure 3.7 shows a histogram of the variable along with the frequencies. It can be seen that the values of this variable follow a normal distribution.

Figure 3.7: Histogram: Mean Age of Knowledge



<u>*Regression results*</u>

Table 3.3 shows the results from the two group t test that tests the equality of means of patent counts for developed versus emerging countries. I find a statistically significant difference in the means at the 95% confidence interval. Thus the data support hypothesis 1A.

Table 3.3: T test results for hypothesis 1A

Group	Obs	Mean	Std. Err.	Std. Dev.	[95%Conf.	Interval]
0	170	4.407552	0.092604	1.207404	4.224743	4.590361
1	262	6.557672	0.111224	1.800312	6.338663	6.776682
Combined	432	5.71156	0.091796	1.907943	5.531137	5.891984
Diff		-2.15012	0.156966		-2.45864	-1.84161
Ha: diff < 0		Ha: diff != 0				
Pr(T < t) = 0.0000		Pr(T > t) = 0.0000				

Further, table 3.4 shows the results from comparing the means of the mean age of knowledge cited between emerging and developed countries. The p value for the two tailed t test is significant at the 0.05 level and thus supports hypothesis 1B thus showing a significant difference between the mean age of knowledge that both groups of countries build upon.

Table 3.4: T test results for hypothesis 1B

Group	Obs	Mean	Std. Err.	Std. Dev.	[95%Conf.	Interval]
0	170	4028.576	93.11815	1214.112	3844.751	4212.4
1	262	3722.643	57.39751	929.0599	3609.622	3835.665
Combined	432	3843.034	50.98761	1059.758	3742.818	3943.249
Diff		305.9324	103.4439		102.6138	509.2511
Ha: diff < 0		Ha: diff != 0				
Pr(T < t) = 0.9984		Pr(T > t) = 0.0033				

Table 3.5 shows regression results pertaining to hypotheses 2A and 2B where the dependent variable is the level of patenting. The first row of results shows the coefficient values associated with the lagged value of the dependent variable. Patents are positively and significantly related to imports thus supporting hypothesis 2A that the level of patenting is positively related to the level of a country's global connectedness. Regulatory quality however has a positive non-significant relationship with patents, thus the data do not provide evidence of support for hypothesis 2B.

Table 3.5 Regression results for hypotheses 2

DV: Patents	Model - Controls	Model H2A	Model H2B
Patents Lag	0.388***	0.337***	0.386***
	(5.34)	(4.78)	(5.29)
Imports		1.123***	
		(3.98)	
Regulatory Quality			0.363
			(1.34)
GDP	-0.455	-1.046	-1.138
	(-0.44)	(-1.05)	(-0.97)
Number of LLCs	0.0103***	0.00740***	0.0104***
	(5.19)	(3.66)	(5.20)
FDI Inflows	0.00715***	0.00609**	0.00716***
	(3.39)	(3.01)	(3.38)
R&D Expenditure	0.767**	0.819***	0.668*
	(3.05)	(3.41)	(2.56)
Population	-0.384	0.131	-0.526
	(-0.39)	(0.14)	(-0.53)
Political Constraints	-0.182	-0.186	-0.115
	(-0.45)	(-0.48)	(-0.28)
Country Category	-0.123	0.211	-0.16
	(-0.38)	(0.65)	(-0.49)
Constant	2.226***	2.272***	2.183***
	(4.95)	(5.31)	(4.82)
N	224	224	224

Table 3.6 shows regression results pertaining to hypotheses 3A and 3B where the dependent variable is the age of technology knowledge. Here too, the first row of results shows the coefficient values for the lagged values of the dependent variable – a first step in the Arellano Bond estimation. The mean age of knowledge is positively and significantly related to imports. This suggests that the age of knowledge cited by patents is positively related to the level of a country's global connectedness. Regulatory quality has a non-significant relationship with the age of cited knowledge, thus the data do not provide evidence of support for hypothesis 3B.

Table 3.6 Regression results for hypotheses 3

DV: Mean Age of Knowledge	Model – Controls	Model H3A Global Connectedness	Model H3B Institutional Development
Age Lag	-0.0202	-0.0562	-0.0262
	(-0.30)	(-0.84)	(-0.39)
Imports		1585.2**	
		(2.67)	
Regulatory Quality			-637.1
			(-1.39)
GDP	5074.6*	3031.9	5065.3*
	(2.29)	(1.31)	(2.27)
Number of LLCs	-6.828	-7.133	-5.971
	(-1.57)	(-1.67)	(-1.36)
FDI Inflows	-0.452	-0.233	-0.924
	(-0.10)	(-0.05)	(-0.20)
R&D Expenditure	241.2	502.5	510.7
	(0.50)	(1.04)	(0.99)
Population	-6127.3*	-6864.4**	-6173.8*
	(-2.32)	(-2.64)	(-2.32)
Political Constraints	1539.7	1497.4	1613.8
	(1.82)	(1.80)	(1.88)
Country Category	-2260.2***	-2217.1***	-1866.2**
	(-4.06)	(-4.06)	(-2.95)
Constant	3412.9***	3446.1***	3344.9***
	(4.90)	(5.04)	(4.75)
N	224	224	224

3.7 Discussion

At the onset, motivated by the recent phenomenon of new technological development by EEs, I find that there are significant differences between the level of international patenting and the mean age of technologies patented by EEs and DEs. More importantly, the focus of examination is the different types of technologies that are developed by EEs who are attempting to catch up with DEs. Thus the above work makes a key contribution by moving beyond innovation - as measured by a simple count of patents - to understanding the actual technology knowledge that resides in a codified form in these patents. By combining insights from technology management with institutional conditions we are able to better understand this catch up effort.

This study makes a key contribution by identifying differences in the age of technologies that countries focus on and the factors that contribute to these differences. This lends a deeper understanding of the nature of technologies that may be most suited for development – given the significant latecomer and institutional challenges that EEs face while catching up. The findings may be extended beyond the context of EEs to apply to other contexts where rapid catchup is achieved despite the competitive disadvantages of being behind the technology frontier.

The findings from this study contribute to our understanding of the phenomenon of innovation in EEs - despite the institutional challenges - and consequent technology catchup by EEs. In addition, the findings inform the process of new technology development in general, in the face of significant latecomer disadvantages. This enhances our understanding of technology evolution by identifying the differential role of governmental institutional support in the protection of new technology knowledge as also access to this new technology knowledge through global connectedness driven by market considerations. Thus it improves our understanding of the influence of institutions on EEs' activities – where significant gaps in the literature still exist (Hoskisson, Wright, Filatochev, & Peng, 2013).

In terms of methodology, the quantitative studies in the dissertation make important contributions to existing EE literature. While most literature utilizes case based, qualitative, and single country study methodologies, this study uses a multi country, multi industry approach to contribute to the breadth of our understanding.

The findings from this study have significant implications for firms and public policy by providing prescriptions to firms about devising appropriate innovation strategies and policy related recommendations to EE governments on how to encourage technological catch-up in their countries. The empirical analysis is limited in the time period that the analysis focuses on. I focus on patenting activities for a time period of 2000 until 2008, despite increasing evidence of catch up from 2009 onwards as well. This is because I only use information on patent applications (which represent knowledge creation) and not patent grants (which represent administrative approval of the knowledge) however the results make important contributions to the literature despite this limitation.

CHAPTER 4 NEW TECHNOLOGY DEVELOPMENT AT THE FIRM LEVEL

4.1 Introduction

Firms from emerging economies are actively engaging in the development of new technology innovations as demonstrated by the increasing levels of patenting by emerging economies (discussed in Chapter 3). In addition, there is also evidence that EE firms are internationalizing rapidly as demonstrated by the increasing levels of outward FDI from EEs (e.g. UNCTAD, 2013). While much of the older internationalization literature, that examined international activities of firms from developed economies, explained international expansion as the means of exploiting internationally the firm specific advantages (FSAs) that firms held in their domestic operations (Dunning, 1980; Hymer, 1976), recent literature - that examines firms from EEs -argues that international expansion by firms is also driven by the need to acquire the FSAs that they lack at home (Child & Rodrigues, 2005; Luo & Tung, 2007). Especially in the case of EE firms - since these firms are behind the technology frontier owing to their country of origin - internationalization serves as a strategy to acquire technological assets that cannot be accessed at home (Gubbi et al., 2010; Makino, Lau & Yeh, 2002; Yiu, Lau, & Bruton, 2007). Accordingly, this chapter examines the impact of firms' internationalization activities on their technological capabilities.

Globalization and the rapid increase in outward FDI and patenting by EE firms (UNCTAD, 2013) demonstrates the development of these capabilities, thus making this an important phenomenon for examination. Further, past research that has investigated the relationship between internationalization and innovation by firms has mostly focused on the performance aspects of innovation and there have been conflicting findings of the existence of a complementary (Golovko & Valentini, 2002; Hitt, Hoskisson & Ireland, 1994; Penner Hahn & Shaver, 2005) or competing (Kumar, 2009; Roper & Love, 2002) relationship between the two. I examine the knowledge portfolio of firms developed through internationalization and argue that internationalization impacts the quality of innovations developed by firms by influencing the novelty of knowledge that firms can access and build upon.

In order to do this, I examine the knowledge portfolio that firms possess by measuring the age of knowledge that firms cite in the innovations that they patent. I hypothesize that the benefits and costs of internationalization with respect to innovation will have a varying effect on the knowledge portfolio of firms and hypothesize that internationalization will have a U shaped relationship with the novelty of firms' knowledge portfolio. I identify the latent mechanisms behind this changing relationship that arise as a result of the benefits from internationalization in terms of access to knowledge, network effects, and learning as also the costs from internationalization in terms of liabilities of foreignness and complexity costs.

I test my hypotheses in the context of biopharmaceutical firms from India. To examine the knowledge portfolio of firms, I use data on all patents filed by these firms with the USPTO and develop measures of the age of the knowledge that these patents build on. I collect internationalization location data from firms' annual reports and code the number of subsidiaries (domestic and foreign) for each firm and their locations (whether developed or developing countries). I use firm level information on firm sales, profitability, age and related variables from the Prowess Database published by Center for Monitoring Indian Economy (CMIE). I develop a panel of firm level data over the years and use a zero inflated negative binomial regression model to test my hypotheses.

4.2 The Phenomenon

In order to understand the internationalization of EE firms and its impact on their technological capabilities I focus my examination on firms from the biopharmaceutical industry of India. Below, I identify the unique characteristics of India in general and the biopharmaceutical industry in particular and explain the reasons why this is a suitable context for examination.

India is considered to be one of the important emerging economies marked by rapid economic growth and in the process of making the transition from emerging to developed country. It is part of the BRIC countries – with Brazil, Russia, & China - four rapidly developing countries and perceived to have very high economic potential. Although Russia has lost this distinction in recent years, India still demonstrates high growth in its GDP and output. Its GDP ranks 10th in the world and 3rd in terms of PPP (World Bank, 2013).

General economic reforms were first adopted in India in the 1980s with extensive liberalization adopted from 1991 when it was required by the IMF to bring about economic reforms as part of the bailout it offered as a result of balance of payment crisis the country faced. The reforms were set up in different forms such as reduction in licenses, red tape, and other regulations needed for the setting up of business ventures. Privatization of many public monopolies was carried out and there was a reduction in tariffs and other trade barriers. Specifically with respect to the pharmaceutical industry as well, many changes were made over time and the government brought about many policy changes to incentivize the development of this industry. For example, 100% FDI in the pharmaceutical industry has been recently approved and licensing restrictions have been relaxed. The government is attempting to develop the biotech industry by drafting a National Biotech Development Strategy and encourage education in biotechnology as well as providing grants and tax benefits for biotech startup firms.

India as Emerging Economy Context

The unique characteristics that India presents as an emerging economy needs further discussion in order to understand the empirical context. Post-independence from 1947 until 1991 India was a mixed economy with a focus on import substitution, protectionism, and excessive regulation. In contrast since 1991 its focus has shifted to liberalization which has led to high growth. This growth has been achieved as a result of privatization, the promotion of trade and international investment, and general pro market reforms.

The Evolution of India

In the pre-1991 India, state intervention and regulation at all stages of business drove technology development. Public sector monopolies drove production and universities were established for the development of science of technology. This model of import substitutions relied on a focus on indigenous firms and other indigenous entities for technology development. Industrial targeting and licensing were the two mechanisms used for the development of the economy (Forbes, 1999).

The balance of payments crisis in the early 1990s prompted a shift in these policies. Post 1991 India focused on a radical shift from protection to liberalization (Bhagwati, 1993). The change in policies involved liberalization, driven by industrialization and a focus on export promotion. The elimination of excess licensing and an improvement in IP regimes by adoption of the TRIPS agreement has also improved the conditions for doing business in the country. India liberalized its FDI policy in 2005, allowing up to a 100% FDI stake in ventures. Many Indian companies are also engaging in outward FDI amounting to about 1.34 percent of the country's

GDP. Some of the important industries driving much of the growth are software, pharmaceuticals, and automobiles.

While annual growth in per capita GDP was about 1.25% until 1980s it has stayed at about 7% from 1990s until now. While much of the population is still primarily engaged in agriculture, the highest contribution to GDP in recent years has been form the services sector (64 percent) with industry and agriculture coming in at 21 and 13 percent respectively in 2014. The major industries are software, petroleum products, chemicals, pharmaceuticals, textiles, steel, transportation equipment, machinery, cement, mining, and construction. Since liberalization, the contribution of total trade in goods and services to the GDP has risen from 16 percent in 1990–91 to 47 percent. This rapid transformation over the past two decades coupled with an ongoing transition make India a suitable emerging economy for examination.

IP regime in India

India's IP legislation was updated through the adoption of the Agreement on Trade Related Aspect of Intellectual Property Rights (TRIPS) as a result of India's inclusion in the World Trade Organization in 1995. India had been a member of the WTO since 1995. This required member nations to establish intellectual property (IP) laws in line with minimum international standards. Since it did not provide product patent protection when the agreement came into effect it was required to implement the change over a period of ten years (2005). India's Patents Act of 1970, amended in 1999, 2002, and 2005 set out the law concerning patents. To comply with the TRIPS agreement, the Patents Act, 1970 was amended to the Patents (Amendment) Act, 1999 through which product patents would be granted to all industries other than pharmaceuticals and agro chemicals.

For pharmaceutical and agro chemical industries, the system of Exclusive Marketing Rights (EMR) was introduced wherein EMRs would be granted for a period of five years for drugs whose patents had been applied for but could not be processed until 2004 which is when the transition period would end. The Patents (Second Amendment) Bill, 2002 was introduced for further changes and a third amendment in 2005 replaced the EMR system and product patents in pharmaceuticals were introduced. Patents are valid for 20 years from the date of filing an application, subject to an annual renewal fee. India's patent law operates under the 'first to file' principle - that is, if two people apply for a patent on an identical invention, the first one to file the application will be awarded the patent. Today there are few major differences between India's laws and those of other developed countries, yet there are significant concerns over IP enforcement due to bureaucratic delays and lengthy litigations.

Biopharmaceutical Industry in India

The pharmaceutical industry of India is an example of rapid development in a technology intensive industry (Brandl & Mudambi, 2014) driven by the efforts of indigenous firms as also institutional support from the government. The pharmaceutical industry in particular has been shaped to a large extent by government policy as also indigenous firms with the development of technology capabilities over the past few years. Below is a discussion of the details of this evolution.

Evolution of the pharmaceutical industry

Prior to the 1970s India was a chief importer of drugs from the developed world such as UK, France, and Germany and foreign firms represented the major chunk of the domestic Indian drug industry. India also followed the patent regulations similar to those in England. Since the 1970s India started focusing on the development of a generics industry to fulfil the needs of the domestic market which was largely unable to purchase the imported drugs at high prices. Public sector companies such as Hindustan Antibiotics Ltd (HAL) and Indian Drugs & Pharmaceuticals Ltd (IDPL) were set up to promote indigenous production. The setting up of research institutions such as Central Drug Research Institute and National Chemical Laboratory helped improve drug development capabilities.

Government regulations in the 1970s and 1980s, allowed Indian biopharmaceutical firms to imitate and develop generics drugs (Nair, 2008). The Drug Price Control Order of 1979 allowed the government to regulate the prices of domestically manufactured drugs thus making drugs available to the majority of the population. Also the inability of the development of the domestic industry under the strict patent regime from before, prompted the government to weaken many patent laws. Thus the Indian Patent Act of 1970 and the 1978 Drug Policy (which allowed for compulsory licensing to domestic firms) were developed which incentivized the indigenous firms. As per this act, the Indian government would only award patents for manufacturing processes and not for products. As a result, indigenous companies began reverse engineering existing drugs developed by foreign companies and developing generic versions. In addition to the above regulations, the Foreign Exchange Regulation Act, which prevented foreign holdings of foreign companies to about 40% all discouraged foreign firms and encouraged operations for domestic firms.

Some of these moves prompted MNCs to move out of the country, but this also contributed to the development of the indigenous industry. The MNCs that continued to operate in India focused on setting up formulation units and restricted foreign imports under government pressure. Thus, the focus of both indigenous and MNCs on formulation and manufacturing led to the development of a strong generics industry.

The indigenous firms developed their basic capabilities in process R&D by reverse engineering and duplicative imitation (Kale, 2005; Kale & Little, 2007). This reverse engineering helped in the development of basic capabilities in the production process as also drug manufacturing, and the emergence of many domestics firms all of which were trying to develop the most efficient process for production. These imitative capabilities are demonstrated by the shortening of the time gap between the introduction of a new drug by a MNC in the global market and its introduction in the Indian market by a domestic firm (Keayla, 1996). Also, the indigenous companies went from a 30 percent market share of the Indian market in 1972 to 77 percent in 2004.

In the 1990s, along with liberalization in other areas, the pharmaceutical industry was also opened up for FDI. These changes prompted the reentry of many MNCs into India which increased competition to the domestic firms and encouraged the development of new technological capabilities by domestic firms who had until then relied on manufacturing capabilities only. At the same time, many Indian firms also ventured into exporting into international markets. Here, they developed the capabilities of creative imitation which involved the development of some processes that would not infringe on existing patents and develop new processes of patentable value (Kale, 2005; Kale & Little, 2007). This allowed the entry of Indian firms to the global generics industry in not just other developing countries but other advanced markets too. This also helped develop their capabilities in navigating international patent regimes which they had not been exposed to until then as a result of domestic operations. These capabilities would be useful later on when they would start making more important innovations and patenting them.

In order to enter the global generics industry, Indian firms first developed marketing infrastructures in many advanced countries such as in the US by acquiring American firms or forming alliances with them. Over a period of time many firms focused on getting FDA approvals from the US FDA and other developed construes for their manufacturing facilities as also filing for Abbreviated New Drug Applications (ANDAs). All of the above helped in rapid development of the basic capabilities and infrastructure in terms of international selling and basic R&D that had been developed over many decades by other advanced country firms and which Indian companies were able to develop over a span of a few years. These capabilities in generic R&D formed the foundation of the research capabilities that would be useful over the coming years and into the present (Kale, Hanlin, & Chataway, 2013).

India's inclusion in the WTO in 1995, necessitated the adoption of the TRIPS agreements which was completely adopted by 2005. Along with increased liberalization, these factors led to the industry undergoing a second wave of change. TRIPS necessitated a shift in focus from process innovation capabilities to drug discovery research and drug delivery system research. These capabilities represent a dramatic step up from the previous stage and require significant knowledge and resources. Despite basic capabilities in research, the absence of the tremendous financials resources and R&D talent in discovery research still pose many challenges for EE firms. Thus EE firms have now been engaging in collaborations with advanced country firms and research organizations as mechanisms to learn more about developing technological capabilities (Kale et al., 2013). These collaborations are carried out by firms and research institutions as well. In addition to channeling profits from the generics business to advanced R&D, EE firms also engage in out licensing of molecules of drug delivery systems, which they develop independently but do not possess the financial or infrastructural resources to be able to operate along the complete value chain form discovery to marketing.

As of 2014, The Indian biopharmaceutical industry is ranked third largest in volume and 10th largest in value worldwide (IBEF, 2014). During 2013-14, pharma exports from India were US$ 14.55 billion and the share of new formulations was 71 per cent (PEPC, 2014). Indian pharmaceutical firms have been show increases in R&D spending both in absolute terms (approximately Rs. 7 billion) and as a percentage of revenues (8-11 percent) (ICRA, 2014). The R&D intensity of Indian firms was about 2 percent in 2000 it had shown a steady increase to about 7 percent by 2011 (Joseph, 2011) however it is still lower than most developed country firms at about 18 percent. Indian firms are also moving from traditional drug segments to more complex therapy segments like injectables, inhalers, dermatology, controlled-release substances and biosimilars (ICRA, 2014).

R&D in Indian Pharmaceutical Industry

Research and development costs are estimated to be 40 percent less than those in the US (Mani, 2006). The development costs are lower partly due to low costs of regulations surrounding clinical trials. In addition the abundance of skilled labor with strong chemistry skills also aids in R&D. India has the largest number of US FDA approved manufacturing plants outside USA. Also, the largest number of Drug Master Filings (DMF) outside USA are made by Indian firms.

Post liberalization in India the technological capability of the country has improved and there has been an increase in number of technology based new ventures in the country, international investments by indigenous Indian firms, surge in the exports of high technology products, and consequent updation of technological capabilities of indigenous firms (Bowonder

& Richardson, 2000). Feinberg & Majumdar's (2001) examination of the Indian pharmaceutical industry from 1980 to 1994 resulted in the findings that knowledge spillovers only occurred between different MNCs and not between MNCs and local firms as a result of weak appropriability regimes.

Kathuria (2001) and Manral (2001) find that knowledge spillovers are not a direct consequence of foreign firms' operations in EEs but are contingent upon the investments made by local firms to update their knowledge and technology. The results vary based upon the nature of the industry that firms operate in, in that the presence of local firms' own R&D capabilities is more important in 'scientific' industries than in 'nonscientific' ones for spillovers to take place. Medcof (2007) argues for similar spillovers between MNCs and their subsidiaries in EEs which leads to technological upgrading of the country in the context of MNCs and their subsidiaries in China. Examining differences in the strategic activities of local firms and subsidiaries of MNCs in EEs, (Kumar & Aggarwal, 2005) find that local firms' R&D activities focus on developing their own capabilities using technology from imported products, whereas MNC subsidiaries' R&D activities are focused on exploiting the country specific advantages.

The Indian pharmaceutical industry today consists of firms focusing on bulk drugs and formulations. As described below it has evolved over time as a result of policy interventions (Chaudhari, 2005; Mani, 2006). Table 4.1 draws from the analysis of the industry by Chaudhari (2005) and identifies the implications of the evolution of the industry on the R&D activities and innovativeness of domestic firms.

Table 4.1: The evolution of the biopharmaceutical industry of India (adapted from Chaudhari, 2005)

Time Period	Patent Regime	Dominant Firms	Industry Characteristics	Innovation & R&D
1947 until early 1970s	Similar to developed world; product and process patents recognized	Foreign firms	High priced essential drugs, dependence on imports	Innovation by MNCs
Late 1970s until 1980s	Product patents done away with; only process patents recognized	Exit of foreign firms; growth of indigenous manufacturing firms	Development of manufacturing capabilities; self sufficiency in drug availability; import dependence reduced	Reverse engineering; process innovations
1990s until 2005	The slow adoption of TRIPS; economic reforms	Continued growth and consolidation of indigenous sector	Increased exporting by indigenous firms; slow reentry of foreign firms	Speed and capabilities in process innovations for generics; developing capabilities in formulations
2005 until present	TRIPS compliance	Reentry of foreign firms; increased competition	The expiry of patents on blockbuster drugs; Foreign firms establish R&D units; Indigenous firms make R&D investments	Increased drug development by foreign firms; emergence of CROs

Government policy

The National Pharmaceuticals Policy (2006) provides many fiscal incentives for the promotion of R&D by pharmaceutical firms. Tax exemptions are provided for resources and investments made into R&D activities for a period of 10 years considering the long time period for drug development. The government also incentivizes R&D intensive companies by giving them price benefits for certain drugs. In addition, Pharmaceutical Research and Development Support Fund (PRDSF) has been set up to provide funding for R&D. the government also supports the development of orphan drugs through other initiatives. Thus the government policy seems to have systems and incentives in place for R&D in the pharmaceutical industry. The implementation of these policies will be discussed later.

The Indian patent Act of 1970 greatly incentivized the development of the generics industry due to the exclusion of product patents. With India's inclusion in WTO this changed and the TRIPS regime was adopted in 2005. In order to adopt full compliance of TRIPS in 2005, certain steps were introduced in phases. Exclusive Marketing Rights (EMRs) were introduced in 1995 as a precursor to product patents. Post 2005 though TRIPS compliance introduced pressures on the indigenous industry to change its strategy. Firms could now focus only on off patent (generic) drugs for manufacturing or develop drugs in developing country diseases that were not important for developed country firms or partner with foreign firms to manufacture. This lead to the rise of clinical trial and R&D outsourcing (discussed in detail below).

Despite the above policy measures in place that were meant to incentivize R&D only a handful of firms are active in new drug discovery research (Chaudhari, 2010). Since private firms do not have the capabilities or the financial resources necessary in the successful discovery, manufacturing and selling of new drugs globally i.e. operating along the entire value chain, most firms with strengths in formulations now develop new molecules and license them out to foreign firms at early stages of development and clinical trials. As a result the focus of drug development is on developed world diseases such as obesity and not on developing world diseases such as tuberculosis.

Thus the empirical context of examination is well suited for the research question I examine. The biopharmaceutical industry is very R&D intensive since successful products generate long term revenue streams. Hence innovation performance and consequently the types of technologies that firms innovate in are especially important in the context of this industry. The emerging economy context of firms from India is also relevant since this industry in India has shown the presence of a strong generic pharmaceutical industry traditionally but firms are now attempting to catch up rapidly with multinational firms from the developed world (e.g. Dr. Reddy's Limited, Biocon Limited). Further, recent improvements in IP institutions (e.g. TRIPS agreement, 2005) have made incentivized the development and protection of innovations in the form of patents and hence it is appropriate to examine the internationalization and patenting activities of firms from the Indian biopharmaceutical industry.

4.3 Theoretical Background

Innovation by EE firms: Impact of home country conditions

Institutions in EEs in general are not as stable as the ones in DEs (Young, Peng, Alstrom, & Bruton, 2008). As a result of these institutional differences, the incentives and challenges for innovation in developed and emerging economies differ considerably. The institutions of a country plays an important role in the development and appropriation of innovations. Institutions support not only the development of innovations by allowing firms to access resources required for the R&D for new technology development, but also incentivize the appropriation of rents from the commercialization of these innovations by protecting the intellectual property embodied in these innovations. National innovation systems such as public research institutions (Mazzoleni & Nelson, 2007), industrial clusters (Furman, Porter, & Stern, 2002), and educational institutions (Varsakelis, 2006) support new technology development.

EEs in general do not show the presence of exhaustive regulations with respect to patent laws and intellectual property rights (Peng, Wang, & Jiang, 2008) which reduce the barriers to imitation significantly and thus make innovation an unfavorable strategic choice (Stack, 2011). Enforcement of contracts and resolution of disputes is more difficult in emerging economies. EEs are also generally considered to be apathetic towards intellectual property rights protection, and are tolerant towards counterfeiting, fake goods, and piracy, and other forms of IP rights infringements (Wang, 2011).This poses significant challenges for innovating firms which have very few ways of safeguarding their proprietary knowledge which can potentially give them a competitive advantage in the market (Grant, 1996; Zhao, 2006).With respect to the role of governments in EEs, there is a high degree of governmental intervention in firms' activities, and the unpredictability of government policies and bureaucracy makes it difficult for firms to navigate operations (Khanna & Palepu, 1997). On the other hand, since the regulatory systems in EEs are less developed, they present fewer delays and lesser friction when companies bring innovative solutions to the market (Govindarajan & Trimble, 2012).

Access to research and educational institutions and the state of capital and labor markets are important factors that impact business activities (Bartholomew, 1997) by affecting access to resources necessary for innovation. For firms in EEs, access to financial resources is often a major hurdle due to the underdevelopment of capital markets (Stiglitz, 2000). Another challenge is the availability of technological resources in the form of the presence of institutions supporting new technology development such as research organizations (governmental and non-governmental) and universities, as also skilled human capital such as research scientists and R&D technicians (Archibugi & Coco, 2004; 2005). This is also attributed to the overall lower levels of education in EEs in comparison to DEs. Also, since most EEs are behind the technology frontier they cannot access technology knowledge from other external sources such as related and supporting industries, competitors, and suppliers to the same extent as can DEs (Lundvall, Johnson, Anderson, & Dalum, 2002). This makes advancements in technology and the development of new innovations difficult. The challenges in accessing these input factors pose substantial hurdles to firm activities in EEs.

Internationalization and its benefits and costs

Given the above challenges for the development of technology innovation in their home countries, internationalization offers many opportunities to EE firms to overcome these home country challenges. Internationalization can be defined as 'expanding across country borders into geographic locations that are new to the firm' (Hitt, Hoskisson, & Ireland, 1994: 298). Extant research on internationalization has identified different costs and benefits that arise from international operations and consequently has different implications for innovation. At the onset, international operations generate significant costs in the form of *search costs* associated with identifying international locations and entry strategy, and then implementing the strategy. With continuing operations come the *coordination costs* of coordinating international activities and managing subsidiaries, in addition to additional costs of rising complexities (Granstrand et al., 1997; Von Zedtwitz & Gassmann, 2002). However, internationalization offers significant benefits in the form of *access to newer markets* where firms can market their existing products and thus improve performance (Kotabe et al., 2002). The other important benefit from internationalization is the *access to resources* that are not available domestically (Hitt et al., 1997; Kobrin, 1991; Kotabe, 1990, Kotabe et al., 2002). Next I discuss the costs and benefits of internationalization specifically with respect to innovation for EE firms in order to highlight the implications of internationalization on the knowledge portfolio of firms.

EE firms' internationalization: Benefits and costs

Internationalization provides EE firms with access to the national innovation systems in other countries (Patel & Vega, 1999) by accessing local firms, customers, and research institutions (Oxley & Sampson, 2004, Santos et al., 2004). This offers many benefits which arise from the economies of agglomeration as a result of colocation with high quality suppliers, researchers and other human capital, and the presence of related and supporting industries in international locations especially those in developed economies (Kafouros, 2006; Santos et al., 2004). In addition, firms can also learn through spillovers from other firms by collocating in clusters in international locations (Liu & Buck, 2007). The need to develop technological capabilities and develop technologically sophisticated products means that internationalization allows EE firms to access such products available in international markets.

Thus internationalization brings access to technology assets that EE firms would otherwise have been unable to access solely through domestic operations (Kobrin, 1991; Kotabe, 1990). One of the major costs of internationalization is the liability of foreignness (Zaheer, 1995). While all firms irrespective of origin face the liability of foreignness while engaging in outward FDI, firms from EEs have the added costs due to latecomer disadvantages and costs of learning about operating in new institutional systems due to the institutional deficiencies at home.

Technology knowledge and innovation

Innovation is a knowledge intensive process (Nonaka & Takeuchi, 1995) and firms' research and development activities lead to creation of new knowledge (Griliches, 1979; Mansfield, 1984). Technology knowledge is important because it is one of the sources of competitive advantage for firms (Criscuolo et al., 2005). However, not all kinds of technology knowledge lend to equivalent features for competitiveness. Knowledge can be classified along different dimensions. Successful innovations depend on the ability to build on a firms' existing knowledge (Nonaka, 1994) and draw from external sources of knowledge (Cohen & Levinthal, 1990).

Some research argues that older, well established knowledge is more reliable and hence aids innovation (March, Sproul, & Tamuz, 1991). Since innovative activities present uncertainties in the success and acceptance of the outcome, using older knowledge helps reduce these uncertainties associated with the outcome of innovation. Older knowledge that has been used for prior applications is generally more reliable and legitimate (March, 1991) and robust (Hutchins, 1983). Thus it increases the probability of generating successful innovations.

The older that the knowledge is the more established are the details and applications of that knowledge thus making it easier to make incremental improvements to develop new innovations (Ahuja & Katila, 1999; Katila, 2002). This knowledge has been used for multiple applications and its effects have been tested and any errors corrected. Thus this knowledge has been polished over time and is more sophisticated. Older knowledge, by virtue of its age is also considered more legitimate by users and hence the probability of investing in and commercializing ideas based on old knowledge are higher (Katila, 2002). At the same time, older knowledge offers fewer opportunities for recombination (Fleming, 2001) and has higher risks of obsolescence (Sorensen & Stuart, 2000).

With time, knowledge becomes old and obsolete and can no longer fulfil the needs of the current environment (e.g. Eisenhardt, 1989; Thompson, 1967). Thus reliance on older knowledge may not be conducive for the development of innovations. Firms' innovations often become obsolete due to rapid changes in environmental demands and hence there is constant pressure for firms to keep up with these changes (Sorensen & Stuart, 2000). The capability to access and use recent knowledge also helps firms to keep track of trends in technological trends and allows them forecast emerging technologies and prevent being locked out of certain areas due to a lack of investments early on (McGrath, 1999). The capability building argument described above is most crucial to firms from EEs who face the challenge of rapid innovative capability development due to latecomer disadvantages.

In addition, the use of new knowledge offers benefits for innovation. Accessing and using new knowledge helps firms build early mover advantages and stay competitive. Use of recent knowledge thus prevents obsolescence (Sorensen & Stuart, 2000) since firms that don't recognize changes in technology in time may be locked out of investments in new technologies with increasing barriers to participate in new technologies due to already established technology and product standards by other competitors. Also since new technology knowledge takes a long time to diffuse across firms, firms that develop this knowledge can extract higher rents from their innovations prior to diffusion.

However, novel technologies also present risks in that they are less likely to be successful as they require greater change in stakeholder investments, and are further away from previous technological solutions in terms of established, scientific knowledge. Further, newer technologies will take longer to develop as there is greater uncertainties regarding their safety, and externalities.

Thus the use of both old and new knowledge offers benefits and costs to innovation and firms have to make decisions on the types of knowledge to access and build upon to develop new innovations. Accordingly, I measure technology knowledge patented on the basis of novelty of the field of technology knowledge. For example, knowledge on steam engine technology is relatively well established since the technology was established a long time ago as against knowledge in nanotechnology which is a novel field and hence the opportunities for technology innovation are ample but the novelty also makes it harder to develop successful innovations. Below I argue that the strategic decisions that EE firms make with respect to internationalization will have different impacts on the age of the knowledge that they use in innovations.

4.4 Hypothesis Development

Low levels of internationalization

Low internationalization pertains not only to firms that have relatively few international subsidiaries but also firms that are new and hence have just barely started internationalization. While much of the older internationalization literature (that examined internationalization from the perspective of firms from DEs) explained international expansion as a means of exploiting the FSAs that firms held in their domestic operations, recent literature (that examines firms from EEs) argues that EE firms lack the traditional FSAs held by DE firms such as technological and innovation capabilities. Accordingly, much of the internationalization by EE firms is driven by asset seeking motivations prior to the exploitation of existing assets in international locations (Child & Rodrigues, 2005; Luo & Tung, 2007).

Since EE firms are behind the technology frontier, much of their internationalization is driven by the need to develop technological capabilities in order to stay competitive with other EE and DE firms. As a result, internationalization provides benefits in terms of improved technological capabilities to EE firms. This is because firms can learn through spillovers of knowledge by collocating in international knowledge networks (Hitt et al., 1997; Kafouros, 2006; Von Zedtwitz & Gassmann, 2002). They can also access local skilled human capital that may be absent domestically (Cheng & Bolon, 1993). Thus access to these resources and networks also provide learning benefits to firms which help develop their knowledge base to develop new innovations.

Firms in EEs are not totally devoid of all innovation capabilities though. Many EE firms have developed significant strengths in innovation in specific areas. For example, pharmaceutical firms in India have strengths in generic manufacturing and consequently possess superior capabilities in process innovations than firms from DEs (Chaudhari, 2010; Joseph, 2012). Despite this, many of these technology capabilities that are domestically developed, reside in mature fields of knowledge and do not ensure competitiveness with increasing competition from DE firms.

Novel technology innovations require greater resource commitments (Stringer, 2000) compared to mature technologies which have been prevalent in the industry for some time and are well understood by the industry players. Since the capital markets in EE firms' home countries are underdeveloped (Stiglitz, 2000) internationalization is vital for access to these resources in international markets. Firms also face the risk of being locked out of the industry in case they are unable to adopt the dominant technology that emerges over time (Schilling, 2002). Hence, it is strategically important for EE firms to invest in novel technologies in order to stay competitive in the increasingly global markets. Accordingly, internationalization is crucial for accessing knowledge in new areas and developing innovation capabilities in new technologies.

Thus internationalization allows EE firms to develop the technology based FSAs that they lack. Especially, in the case of EE firms, the potential to utilize these technology assets and generate returns outweigh the costs of internationalization. Since EE firms already have some strengths in older technologies as described above, their internationalization will be driven by the search for novel technologies. Thus internationalization provides tremendous learning benefits to firms that would otherwise have not developed capabilities in novel technologies by continuing to stay at home. Accordingly, the immediate benefits of internationalization can be witnessed through an increased innovation in new technologies. Accordingly, I hypothesize

> *Hypothesis 1a. Other things being equal, internationalization has a negative relationship with the age of technology knowledge base at low levels of internationalization i.e. internationalization will lead to patenting innovations citing newer knowledge.*

Moderate levels of internationalization

With increasing internationalization though, the learning benefits that are offered by internationalization do not increase simultaneously. Increasing internationalization does not continue to offer further new knowledge spillovers at the same rate. Further, firms' strategic focus also moves from an acquisition of new technology assets to exploitation of economic gains from the already acquired technology assets in new locations (e.g. Lu & Beamish, 2004). The substantial R&D investments made for the development of technology innovations necessitate the selling of these products to larger international markets so that firms that are carrying out R&D activities can generate adequate returns for their investments (Bruton & Rubanik, 2002; Bruton, Dess, & Janney, 2007). At this stage of internationalization, EE firms will behave similar to DE firms exploiting their existing FSAs.

In addition, once firms have already established some strengths in new technologies, it is more efficient to continue to focus on those areas instead of attempting to branch out into further new areas. Older knowledge by virtue of its age is considered legitimate and due to being well established is more reliable (Katila, 2002). Products based upon older technology knowledge are already available for sale in EEs, and EE firms have established strengths in the development of such products. World production for older technology products has also been largely delocalized to EEs, hence it is easier for latecomers from EEs to exploit their innovations in other international markets. Accordingly, I hypothesize

Hypothesis 1b. Other things being equal, internationalization has a <u>positive</u> relationship with the age of technology knowledge base at <u>moderate</u> levels of internationalization i.e. internationalization will lead to patenting innovations citing older knowledge.

<u>High levels of internationalization</u>

With time, as knowledge ages, firms 'deplete and eventually exhaust the pool of knowledge combinations' that can be of economic value (Katila, 2002). Thus generating newer combinations from older knowledge becomes more and more expensive and complex since the lower hanging fruit in the form of simpler innovations have already been picked (Ahuja & Katila, 1999; Fleming, 2001). Thus, over time, with increasing internationalization, the potential to exploit existing mature technology innovations in international markets will be diminished. Thus firms have to search for novel technology knowledge in order to continue to stay competitive in different markets. Engaging in research in novel technologies can lead to greater possibility of creating breakthrough innovations (Ahuja & Lampert, 2001) which firms can then use to create value across multiple international markets at high levels of internationalization.

Highly internationalized firms also possess geographically dispersed R&D units (Von Zedtwitz & Gassmann, 2002; Kurokawa, Iwata, & Roberts, 2007). Thus these firms can draw on local knowledge from these dispersed country locations and by using local human capital in these international locations (Kafouros, 2006). Further, not only do highly internationalized firms have access to more diverse sources of knowledge but also have more opportunities for organizational learning while managing the diversity of their international operations (e.g. Hitt et al., 1997; Kafouros, Buckley, Sharp, & Wang, 2008). Thus the opportunities for novel knowledge creation are higher. In addition, when firms have a large international portfolio they also have significantly higher resources to devote to research and development for new technology products (Kobrin, 1991). The ability to invest more will translate to the development of a knowledge base of novel technology knowledge. Accordingly, I hypothesize

Hypothesis 1c. Other things being equal, internationalization has a <u>negative</u> relationship with the age of technology knowledge base at <u>high levels</u> of internationalization i.e. internationalization will lead to patenting innovations citing newer knowledge.

4.5 Methodology

<u>Data</u>

The study examines the international and patenting activities of firms from the Indian biopharmaceutical industry. In order to create the sample of firms for this study, I identified firms that were classified as pharmaceutical and biotechnology firms in the CMIE (Centre for Monitoring the Indian Economy) Prowess database, categorized according to the National Industrial Classification of India, which contains detailed information on firms in the biopharmaceutical industry in India. I then selected firms engaging in outward FDI as firms with at least one international subsidiary in the time period from 1997 to 2013. The resulting sample consists of a total of 64 firms. I collected detailed information about the subsidiaries of these firms to create measures for their international activities. I also collected information on the patenting activities of these firms based on their patents filed with the USPTO in order to develop the measure of their knowledge portfolio. Lastly, I collected financial and other information about firms from the Prowess database to control for various within and between firm differences.

<u>*Measures*</u>

Mean age of knowledge is the key dependent variable of examination. This variable measures the average age of the knowledge portfolio of a firm for a given year. I do this by utilizing information on the age of citations that the focal patents filed by a firm cite as their source of knowledge. To develop this measure, I computed the mean age of all the patents that each focal patent cites. This age is calculated as the difference between the year of the filing of the focal patent and the year of grant of the cited patent. The year of filing of the focal patent is indicative of the time that the knowledge contained in the patent was first generated. The year of grant of the cited patent is indicative of the time that the knowledge contained in the cited patent was verified as novel by the patenting office and was made available for use to others. Thus the number of years that have passed between the grant of the cited patents and the filing of the focal patent is the total age of knowledge that each patent cites. The mean age for all patents granted to a firm for a given year is then computed to generate the age of the knowledge portfolio at a firm year level. *Appendix 2 details the calculation of this measure.*

Level of globalization is the key independent variable. This variable represents the count of total international subsidiaries held by a firm during a given year. Information on this variable was collected from the annual reports of all firms in the sample over the entire time period from 2000 to 2013.

RDintensity is the variable that predicts the effect of internationalization on innovation by firms that don't have any patents. Many firms in the sample have no patents for the period of examination. Further, many of these firms do carry out R&D. This means that there are two types of firms in the sample. There are some firms that perform R&D but are unable to or choose not to translate their R&D into patentable knowledge. There are also firms that do not engage in any R&D and consequently have no patents. The empirical estimation using the zero-inflated negative binomial model requires the specification of variables that will influence the binary outcome. In this case, the appropriate variable is the R&D intensity of the firm. In the ZINB model, R&D intensity is used as a proxy to measure the knowledge of firms that may be carrying out R&D but have no patents and consequently their knowledge portfolio cannot be measured. Information on the R&D expenses and total sales of firms was collected from the Prowess database and R&D intensity was computed at the firm year level.

Control variables I control for various firm specific characteristics. First, I control for the total number of *patents* that a firm has been granted by the USPTO since the age of a firm's knowledge portfolio may be artificially inflated due to a high count of patents. I also control for the number of *Indian patents* that a firm has been granted by the Indian Patent Office which helps to control for the existing, local knowledge that the firm has at home. Further, I control for between firm differences in firm size by using *total assets* as a measure of firm size, differences in firm *age* by measuring the age of a film since its year of incorporation, and differences in firm performance by using the *TobinsQ* ratio, since larger, older, and better performing firms may have more resources for carrying out international expansion and innovation. I control for between and within firm differences in other international activities by measuring the *total exports* in million USD made by a firm for a given year since exporting as an international activity can significantly influence a firm's propensity to engage in FDI (Arnold & Hussinger, 2010; Helpman, Melitz, & Yeaple, 2003).I also control for the number of *R&D labs* that firms have internationally since these can significantly affect the innovative capabilities of firms. In addition, I control for the number of *alliances* that firms have each year since these affect the sources of knowledge that firms can access from other firms and consequently influence the nature of innovations developed. Lastly, I use time dummies for all *years* to control for time variant factors.

Model

The dependent variable of examination is the age of knowledge that a firm possesses as measured by the mean age of the firm's cited knowledge in its patents. Since age here is a count of the number of years between the development of novel knowledge and its use by the firm in its patents, it is a non-negative count of the number of years. Accordingly the dependent variable can be treated as a count variable and hence Poisson or negative binomial models are appropriate for testing the hypotheses. In this case, since the data are over dispersed, in that the variance of the values is higher than the mean, Poisson is eliminated.

Further, the data show a large number of zeros since there are many firms which have no patents for the period of examination. However, many of these firms do carry out R&D. This means that there are a number of firms that perform R&D but are unable to or choose not to translate their R&D into patentable knowledge. Further, there are also firms that do not engage in any R&D and consequently have no patents. Accordingly, the data are zero inflated and hence I use the zero inflated negative binomial model for testing my hypotheses. A zero-inflated model attempts to account for these excess zeros in the data. This is done by estimating two equations, one for the count model and another for the binary model. The binary model is generally a logit model which models one of the two processes that lead to the zero observation. In this case, that process refers to either engaging in R&D investments or not. The count model then models the count process. In this case it refers to the number of innovations that were generated by firms actually engaging in R&D. Appendix 3 presents details of this methodology.

I also perform the Vuong test (Vuong, 1989) to further test the appropriateness of zero inflated negative binomial versus negative binomial model and find that the negative binomial model specification is rejected.

Accordingly, I test the hypotheses using zero inflated negative binomial analysis (ZINB in STATA) where the dependent variable is the age of a firm's knowledge. *Appendix 3 details the rationale and use of this methodology.* The econometric model I use is as follows:

$Y_{it} = \beta_1 X_{1it} + \beta_2 X_1^2 it + \alpha + u_{it}$

where

Y is the dependent variable i.e. the age of knowledge where i = firm and t = time year

α is the unknown intercept

X_{1it} and $X_1^2{}_{it}$ represent the independent variable i.e. the level of globalization and its squared term

β_1 and β_2 are the coefficients for IVs

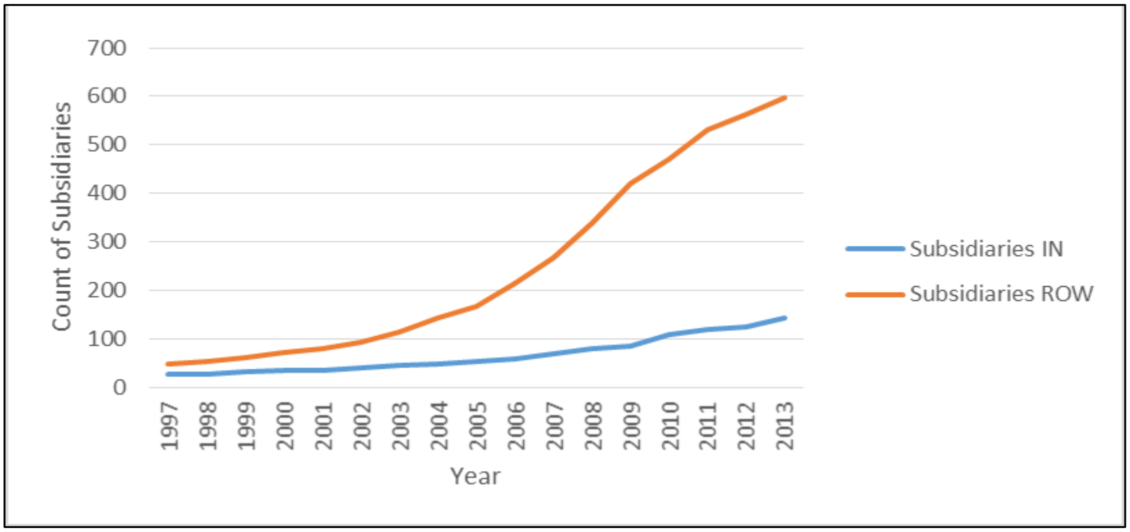
u_{it} is the error term

4.6 Results

<u>*Descriptive Analysis*</u>

In order to understand the impact of internationalization on knowledge portfolio of firms it is important to first understand the nature of technologies being patented by firms. Accordingly, I examine the patenting trends for biopharmaceutical firms from India and examine the age of the knowledge cited in these patents and the scope of the patents.

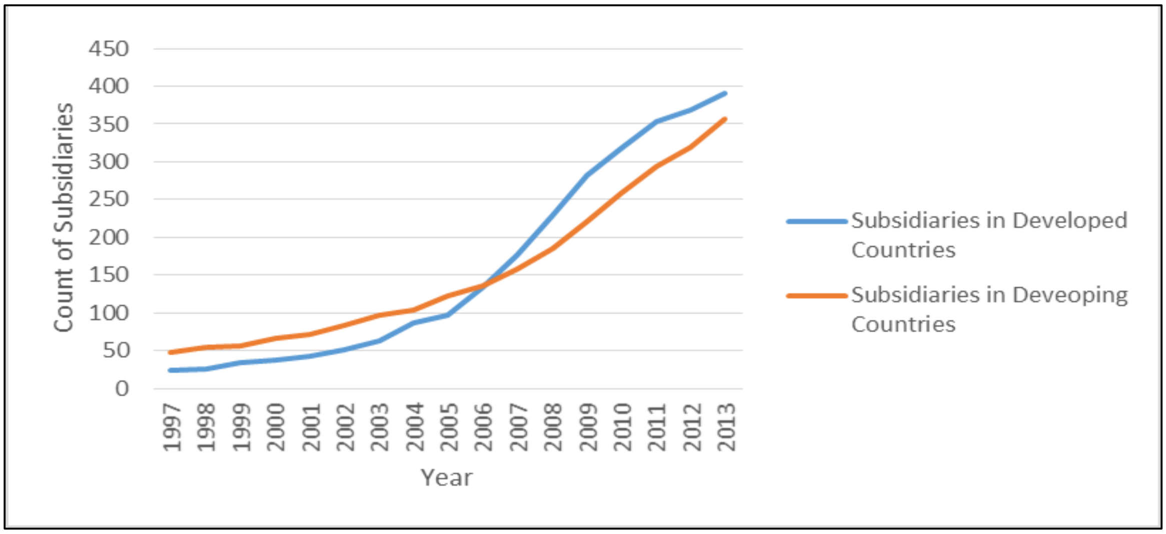
Fig 4.1: Subsidiaries of Indian biopharmaceutical firms in India and rest of the world (ROW)



The descriptive analysis is as follows. Figure 4.1, which shows a graph of the sum of the count of all subsidiaries of firms in the Indian biopharmaceutical industry over the years from 2000 to 2013, shows an increasing trend in the international activities of all Indian biopharmaceutical firms. In addition to an increase in the total number of subsidiaries as demonstrated by the increase in the number of Indian and foreign subsidiaries, I also observe that the increase in the number of foreign subsidiaries is markedly higher as compared to the increase in the number of Indian subsidiaries.

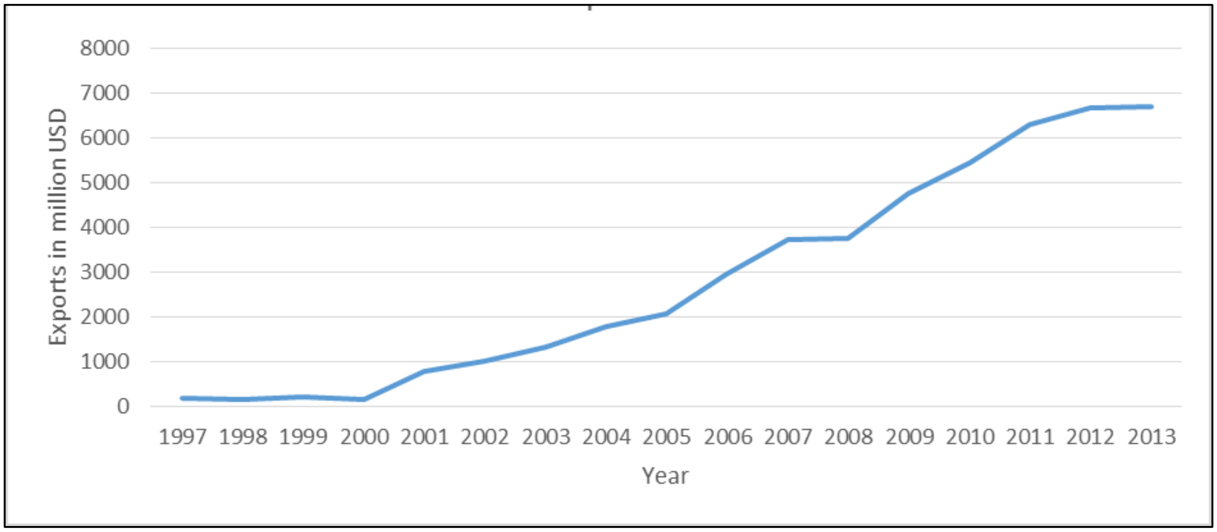
Further, figure 4.2 shows a graph of the trend of count of subsidiaries for all firms as a location wise breakdown of subsidiaries located in developed countries and those in developing countries. Here too I see an overall increasing trend. In addition, the total number of subsidiaries in developed countries exceeded the number in developing countries in 2006 and developed country subsidiaries have shown higher counts ever since.

Fig 4.2: Developed versus developing country distribution of location of international subsidiaries



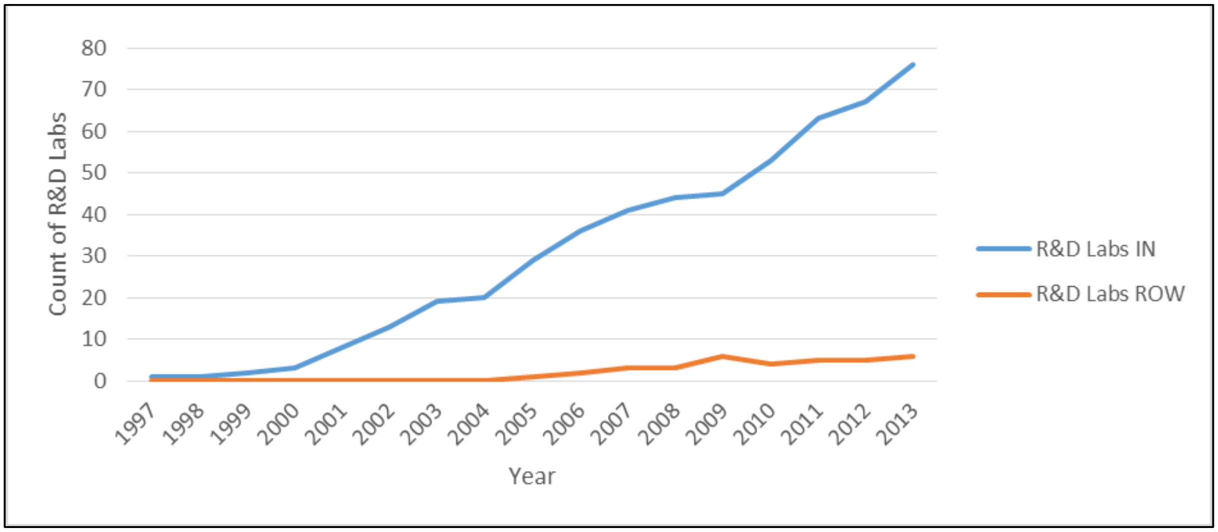
In addition to globalization through FDI as demonstrated by the count of foreign subsidiaries above, I also examine trends in the exporting activities of firms.

Fig 4.3: Exports by firms from the biopharmaceutical industry of India



As seen in Figure 4.3, similar to the increasing trends with respect to outward FDI, here too an increasing trend in the value of exports is observed over the years. After this, I examine the input for innovation i.e. the trends in research and development activities for all firms. Figure 4.4 shows the trend in the R&D labs located in India and the rest of the world for all biopharmaceutical firms.

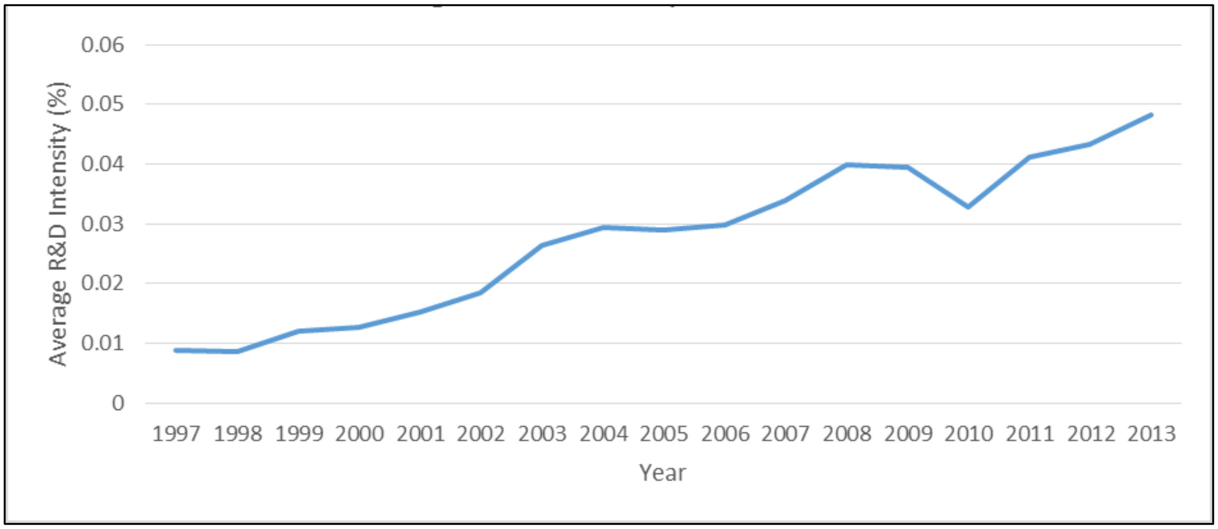
Fig 4.4: R&D labs in India and the rest of the world (ROW)



Contrary to the strong growth trend in the count of both foreign and domestic subsidiaries, in this case, we see only a marginal increase in the count of foreign R&D labs, with a significant increase in the number of Indian R&D labs. Thus, the data seems to suggest that despite increasing internationalization as seen through the subsidiary count and export data, most of the R&D carried out by the firms is still concentrated at home. Further examination of R&D expenses can help to shed more light on this phenomenon.

Figure 4.5 shows the average R&D intensity of all firms for a given year calculated as a percentage of R&D expenses to total sales for each company. Although this figure shows an increasing trend over the years, but the overall R&D intensity percentage ranges from 1 to 5 percent with a maximum of 5 percent which is much lower than that of most firms in the developed world. Despite this the data do suggest that Indian firms have been allocating more and more resources to their research and development functions.

Fig 4.5: Average R&D intensity of Indian biopharmaceutical firms



After examining the trends in internationalization and R&D activities, I examine the trends in the output of innovation namely the patenting activities of Indian biopharmaceutical firms.

Fig 4.6: USPTO patents filed by Indian biopharmaceutical firms

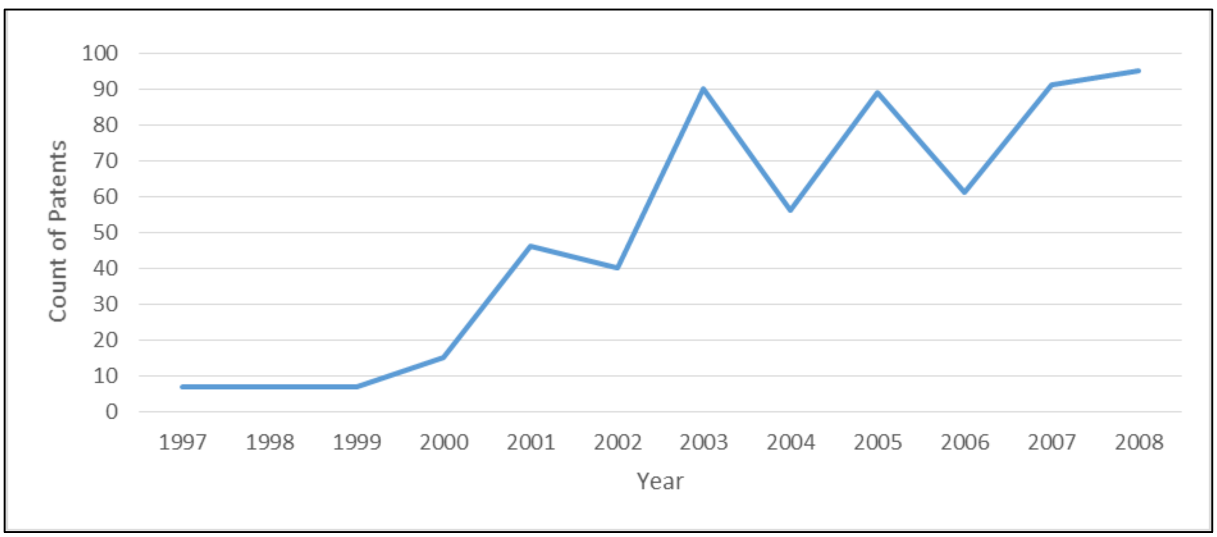
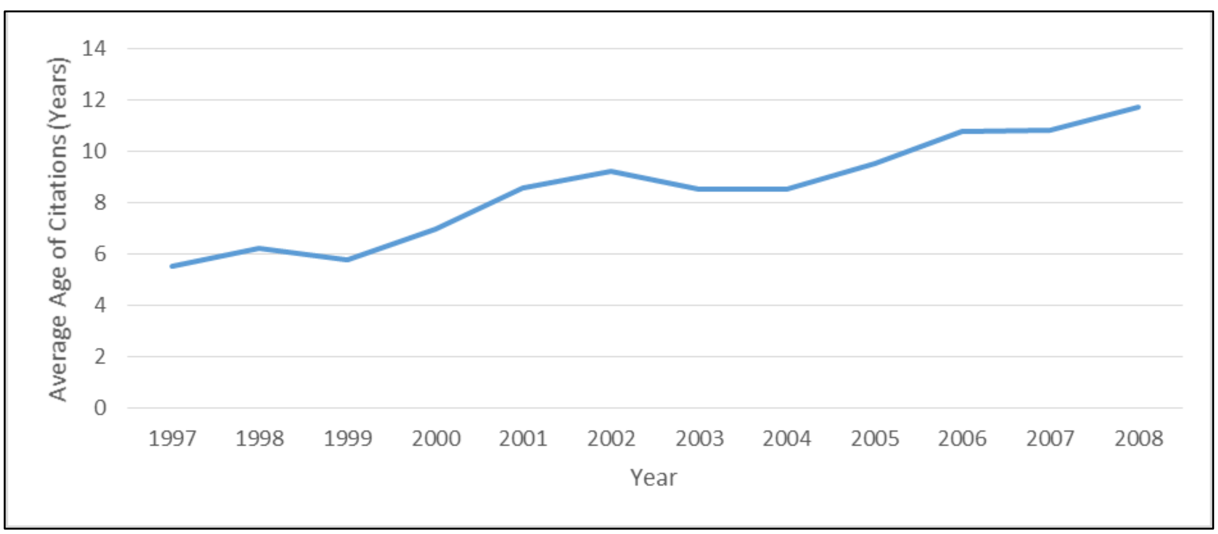


Figure 4.6 shows the trend in the count of total USPTO patents for all firms, which is as expected shows a growing trend. This is in line with extant research that shows increasing patenting activity by firms from EEs.

I then examine the types of technologies being patented by examining the age of the knowledge that these patents cite. To do this, I compute the mean age of knowledge variable which is the average age of all the patents that each patent cites. This is the key dependent variable of the study. Figure 4.7 shows a graph of the mean of this variable across all firms in the industry. There is a definite growing trend in the age of citations growing from about 6 years in 1997 to about 12 years in 2008. This interesting graph seems to suggest that the average age of knowledge cited in patents filed by these firms is getting older. Since the variable takes into account the count of total patents being filed, it eliminates any artificial inflation in the age due to an increase in the count of total patents. Thus the data present interesting evidence for further examination – what could be the reasons why despite increase in the volume of patenting the nature of technologies being patented in are getting older.

Fig 4.7: Mean age of knowledge of patents filed by Indian biopharmaceutical firms



Descriptive Statistics

Tables 4.2 and 4.3 show the descriptive statistics for the variables. There is wide variation in the values of the dependent variable ranging from 0 to 3654 with a mean of 122. The minimum values of the level of globalization are also at 0 with a standard deviation higher than the mean.

Table 4.2: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
MeanAgeofKnowledge	256	122.7	337.6523	0	3654
LevelofGlobalization	1085	3.892166	8.709878	0	69
LevelofGlobalizationsquared	1085	90.94101	364.9128	0	4761
LevelofGlobalizationcubed	1085	3312.359	17870.33	0	328509
Patents	2734	0.332846	1.431841	0	24
IndianPatents	1085	0.776037	3.074802	0	42
TotalAssets	2007	130.5869	341.587	0	3787.55
Age	2734	18.55304	13.5372	0	96
TobinsQ	2104	11.81343	110.2805	0	3486
TotalExports	299	159.4171	229.0667	0.01	1241.19
RDLabsForeign	2734	0.012802	0.158376	0	4
Alliances	2734	0.091075	0.387474	0	4
RDintensity	1081	0.029685	0.051331	0	0.835938

Table 4.3: Pairwise correlations

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Mean Age of Knowledge	1												
2	LevelofGlobalization	0.0022	1											
3	LevelofGlobalsquared	0.0243	0.9317	1										
4	LevelofGlobalizationcubed	0.0231	0.8258	0.9661	1									
5	Patents	0.0584	0.3145	0.2298	0.1691	1								
6	Indian Patents	-0.0277	0.0155	-0.0061	-0.0129	0.2217	1							
7	Total Assets	0.0461	0.7158	0.6275	0.5333	0.5019	0.0366	1						
8	Age	0.1324	0.2204	0.1494	0.108	0.209	0.0707	0.3335	1					
9	TobinsQ	-0.0264	0.3659	0.3181	0.3066	-0.008	0.1948	-0.0006	0.0137	1				
10	Total Exports	-0.0123	0.6158	0.5863	0.5544	0.4307	-0.0211	0.9226	0.3567	0.0847	1			
11	RDLabs Foreign	-0.0343	0.3601	0.2736	0.1768	0.2474	-0.011	0.2327	0.0919	-0.0072	0.0403	1		
12	Alliances	0.1479	0.247	0.2079	0.1678	0.2817	0.1916	0.2856	0.1543	-0.0156	0.169	0.0287	1	
13	RD Intensity	-0.0248	0.2132	0.1707	0.146	0.189	-0.0014	0.26	0.0912	-0.0546	0.459	0.0764	0.0886	1

Regression Results

Table 4.4 shows the results from the regression analysis. The level of globalization is negatively and significantly related with age of knowledge. Model 1 shows the model with only control variables. Model 2, 3, and 4 show the regression results with the inclusion of the linear, squared, and cubed term of level of globalization. Model 2 shows that the coefficient of the linear term of level of globalization is negatively and significantly related to the age of knowledge at p values of 0.10. This provides support for hypothesis 1a. With the inclusion of the squared term, the coefficient of the linear level of globalization term continues to remain negatively significant while the squared term is positively significant. This provides support for hypothesis 1b.

Upon inclusion of the cubed term, the coefficient for level of globalization continues to be negative and significant, but the positive coefficient of the squared term loses statistical significance. The cubed term is negatively related with age of knowledge but is also non-significant. Thus hypothesis 1c is not supported by the data. Despite this, the non-significance of the cubed term lends further support for a quadratic relationship since the addition of a cubed term to test for improved model fit is suggested as an important step to check for robustness of quadratic model (Haans et al., 2016).

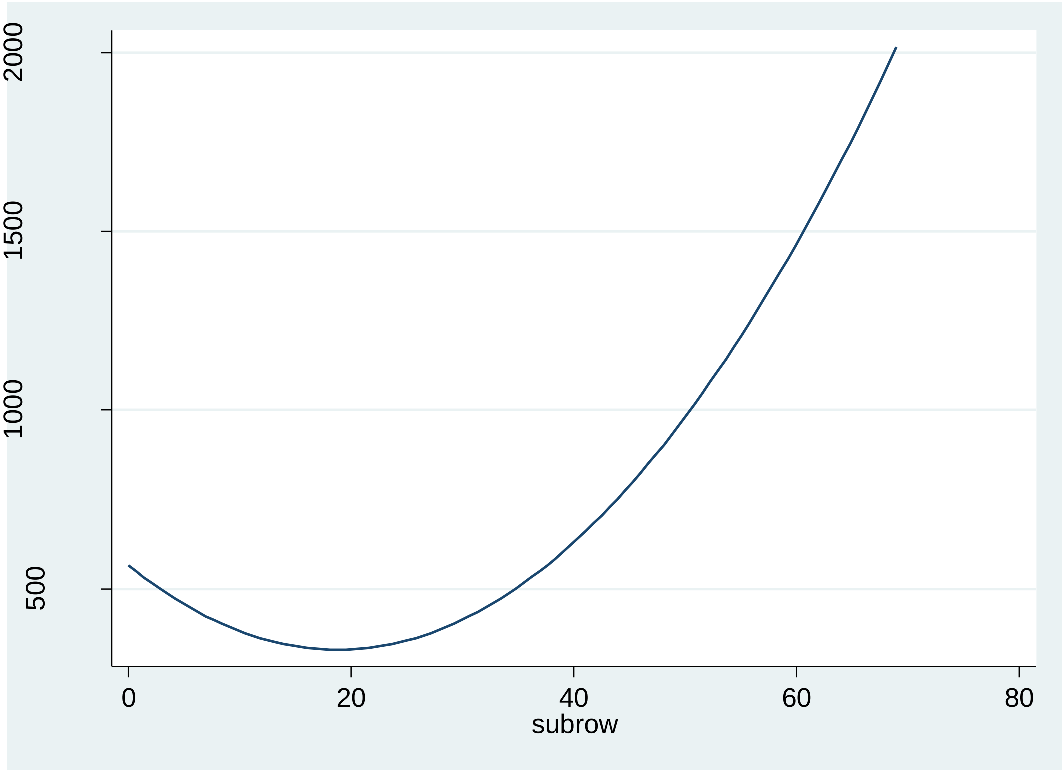
Table 4.4: Regression results: Dependent variable: Mean Age of Knowledge

	Model 1	Model 2	Model 3	Model 4
	Controls	H1A	H1B	H1C
LevelofGlobalization		-0.0191+	-0.157***	-0.211**
		(-1.33)	(-3.56)	(-2.96)
LevelofGlobalSquared			0.00308**	0.00692
			-3.21	-1.67
LevelofGlobalCubed				-0.0000624
				(-0.96)
Patents	-0.0177	-0.0203	-0.0363	-0.0387
	(-0.45)	(-0.51)	(-0.96)	(-1.02)
IndianPatents	-0.0376	-0.0423	-0.0570*	-0.0606**
	(-1.40)	(-1.55)	(-2.49)	(-2.62)
TotalAssets	0.000502	0.000826	0.000706	0.000855
	(0.85)	(1.35)	(1.19)	(1.38)
Firm Age	0.0205	0.0148	0.0141	0.014
	(1.66)	(1.11)	(1.13)	(1.14)
TobinsQ	0.271*	0.312**	0.363**	0.351**
	(2.40)	(2.72)	(3.14)	(2.97)
TotalExports	-0.00282*	-0.00281*	-0.00217	-0.0024
	(-2.05)	(-2.09)	(-1.66)	(-1.80)
RDLabsForeign	-0.340*	-0.202	0.0723	-0.0159
	(-2.13)	(-1.06)	-0.35	(-0.07)
Alliances	0.28	0.336*	0.181	0.215
	(1.91)	(2.25)	(1.17)	(1.37)
Constant	4.087***	4.085***	4.532***	4.643***
	(9.29)	(9.19)	(9.78)	(9.66)
inflate				
RDintensity	-1.591	-1.84	-2.062	-2.024
	(-0.00)	(-0.00)	(-0.00)	(-0.00)
Constant	-21.16	-21.11	-22.45	-22.46
	(-0.00)	(-0.00)	(-0.00)	(-0.00)
lnalpha				
Constant	0.601***	0.591***	0.531***	0.526***
	(5.47)	(5.37)	(4.80)	(4.74)
N	119	119	119	119

Robustness checks

Figure 4.8 shows the fitted values of the regression. As we can see, there is a curvilinear relationship between level of globalization and the mean age of knowledge that firms build upon to innovate.

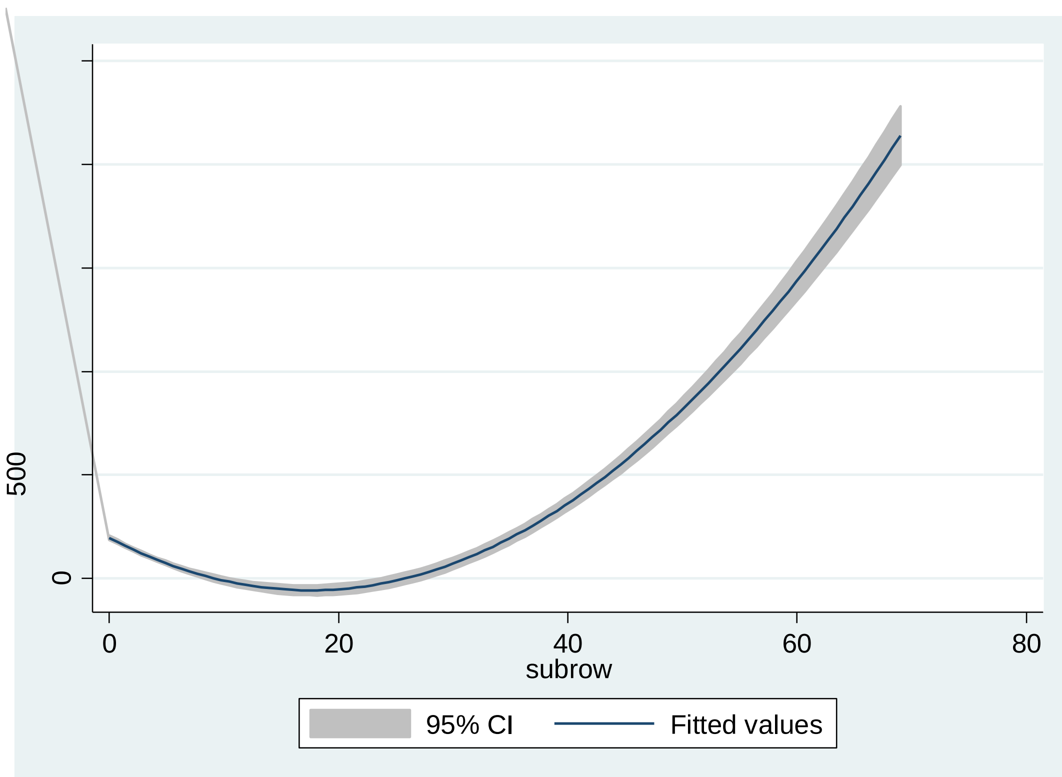
Fig 4.8: Regression predicted values of dependent variable



In order to test for U shaped relationships, research suggests various ways to ensure appropriate model specification. One way is to include the first order independent variable in the regression (Aiken & West, 1991), the coefficient of which was negative and statistically significant in this case. I then build upon the three step procedure developed by Lind and Mehlum (2010) that helps establish a quadratic relationship. First, the significant and negative coefficient for the linear term and the significant and positive coefficient for the squared term indicate the presence of a quadratic relationship.

Second, I calculate the turning point of the equation and make sure that it is well within the data range and not positioned towards the extreme as that would indicate the curvilinear relationship being driven by outliers. Figure 4.9 shows the curve of the predicted age values and the 95% confidence intervals using the regression estimates.

Fig 4.9: Predicted values of dependent variable 95% confidence interval



Lastly, I split the data based on the median level of globalization value following Qian et al. (2010) and run separate regressions for both sub samples. The regression using the low globalization sub sample indicates a negative and significant relationship between globalization and age whereas the regression using the high globalization sub sample produced non-significant results.

4.7 Discussion

Through this study, I hypothesize and find the existence of this U shaped relationship between level of globalization and knowledge portfolio in that the age of a firm's knowledge first decreases with globaalization to reach a minimum age after which the age of a firm's knowledge increases with further globaalization. In addition to this relationship between globaalization and technology knowledge I also theorize the underlying mechanisms that jointly make up this U shaped relationship. These latent mechanisms pertain to the costs and benefits associated with internationalization and patenting and although they are not commonly observable (Haans et al., 2016) – I theorize that these costs and benefits combine in an additive manner to explain the net curvilinear relationship between internationalization and the nature of innovation.

Thus this study makes important contributions to the internationalization-innovation performance literature. However, the internationalization performance literature itself consists of conflicting findings with researchers finding positive (Buhner 1987; Vernon 1971), negative (Brewer, 1981; Ramaswamy 1992) or curvilinear (Capar & Kotabe, 2003; Gomes & Ramaswamy 1999, Hitt et al., 1997; Lu & Beamish 2004) relationship. Further, the internationalization innovation literature also suggests that these two strategies may be complementary (Golovko & Valentini, 2002; Hitt et al., 1994; Penner-Hahn & Shaver, 2005) or competing (Chen et al., 2012; Kumar, 2009; Roper & Love, 2002), consequently the performance implications will very. Through this paper, I build upon these varied findings of literature and argue that internationalization and innovation are related in that internationalization impacts the nature of technologies that they innovate in. Thus I recognize that internationalization is a strategic choice that firms make with motivations that have different implications depending upon the aspect of performance that is under examination.

Literature that examines the relationship between internationalization and innovation primarily explores the performance implications of firm innovativeness (e.g., Chen et al., 2012; Neito & Rodriguez, 2011) or innovation is often conceptualized as a measure of firm performance (e.g., Hitt et al., 1997; Penner-Hahn & Shaver, 2005; Salomon & Jin, 2008; Salomon & Shaver, 2005). Thus, while extant research has examined the relationship between internationalization and innovation performance on the whole, this study adds to a contingency perspective on this relationship by arguing that different strategic choices will have different impacts on the nature of innovation irrespective of the performance implications.

Further, while much of this literature examines the impact of internationalization on innovation performance as measured through some measure of patent counts (e.g., Chen et al., 2012; Penner-Hahn & Shaver, 2005) or new product introductions (e.g., Katila, 2002), this paper examines the impact of internationalization decisions on the nature of innovations and subsequently a firm's knowledge portfolio. Thus the paper goes beyond the immediate performance implications associated with the grant of a new patent or the introduction of a new product for a firm to understanding the nature of the underlying technology being patented by a firm and consequently the entire knowledge portfolio of a firm which has long term implications for the performance of a firm.

The study also has important implications for our understanding of EE firms. The development of technological capabilities is crucial for EE firms to maintain a competitive advantage in increasingly global markets. The latecomer disadvantages coupled with institutional deficiencies that EE firms face at home makes the development of such capabilities very challenging. Despite this, the rapid increase in innovations being patented by EE firms is evidence of the development of these technological capabilities. Research has identified that one of the mechanisms through which these firms are developing new innovations is by increasingly engaging in outward FDI to overcome the challenges at home and access knowledge assets abroad (Makino et al., 2002; Luo & Tung, 2007). Through this study, I identify the nature of technology assets the acquisition of which allows EE firms to catch up with DE firms while managing the costs and benefits of internationalization. Thus I contribute to the growing literature on the strategic motivations of EE firm internationalization by suggesting that EE firms' internationalization is directed towards acquisition of strategic technological assets. These distinct asset seeking motivations of EE firms naturally have an impact on their innovations.

This study goes beyond most studies hypothesizing curvilinear relationships with arguments that "too much of a good thing can be harmful" or that firms "get stuck in the middle" (Haans et al., 2016) by theorizing about the underlying mechanisms that lead to this curvilinear relationship which in effect explains the reasons why a relationship exists instead of simply identifying the nature of the relationship. Further, I theorize the reasons for the existence of this relationship not only between different firms that have different levels of internationalization at a given time (with some firms having many international subsidiaries and some others having very few international subsidiaries) but also within individual firms that move from low to high levels of internationalization over a period of time. This further helps to strengthen the reasons for the existence of this curvilinear relationship between internationalization and technology innovation by using both within and between theorization (Haans et al., 2016).

CHAPTER 5: CONCLUSION

Conclusion

This dissertation examines the recent phenomenon of new technology development and rapidly increasing international patenting by emerging economies. Coupled with increasing output, trade, and inward and outward FDI this recent evidence of rapid development of EEs makes this dissertation a timely study of an interesting, new phenomenon. What makes it even more important is that this rapid development is taking place in spite of the many institutional challenges and resource constraints that these countries face. Thus it is important to understand the phenomenon of international patenting in new technologies by EEs from the perspective of changes in global business landscape.

The studies in the dissertation provide important findings to varied streams of literature – the institutional perspective and its impact on the development and protection of new technologies, the international business literature in the context of emerging economies, the competition literature that deals with catch up in the face of significant latecomer disadvantages, as also literature on new technology development and innovation.

The findings from the dissertation improve our understanding of the importance of institutions on EE firms' activities – where significant gaps in the literature still exist (Hoskisson, Wright, Filatochev, & Peng, 2013). Further, while institutions support transactions and the efficient operations of firms (North, 1991) in general, they play an even more important role in the protection of intellectual property. Hence, this dissertation - by hypothesizing an impact of institutional quality on the novelty of technologies that EEs innovate in - highlights the incentives that institutions offer not only for the development of innovations in general but in particular to innovations in novel, breakthrough technology fields.

Further, through this dissertation I move beyond a general notion of innovation as measured through patent counts to understanding the underlying types of technologies that are codified in the patents. Extant research has identified differences in the technological capabilities of EEs as compared to DEs (Govindarajan & Ramamurti, 2011; Li & Kozhikode, 2009; Kumar, Mudambi, & Gray, 2013). Differences in the availability of skilled human resources necessary for the development of new technologies, institutional systems that support the protection of intellectual property, and access to capital markets for raising necessary resources are some of these factors. Much of this literature focuses on the level of patenting. Despite this, new innovations continue to be developed from EEs as evidenced by the rising levels of international patents that these countries file.

Hence, I focus on the nature of technologies that are patented in addition to the count of patents in order to shed more light on the types of technologies that EEs focus on and find that EEs tend to focus on more older, well established technologies and are still able to generate patentable innovations. This highlights the different pathways that EEs take in order to be competitive (Lee & Lim, 2001) while utilizing their existing knowledge and resources to develop valuable innovations. Hence, the development of the new construct of novelty of technology knowledge through this dissertation makes an important contribution to literature on innovation in emerging economies.

An examination of the phenomenon of new technology development also contributes to our understanding of how firms develop new technologies despite significant latecomer disadvantages and institutional challenges. The dissertation contributes to literature on technology catch up by identifying factors that influence firm catch up such as internationalization especially in the context of emerging economy firms. Owing to their country of origin, most EE firms do not possess the resources that are required for carrying out R&D intensive technological innovation. The lack of these resources can be attributed to institutional challenges (Meyer, Estrin, Bhaumik, & Peng, 2009) such as underdeveloped capital markets, insufficient appropriability mechanisms, and absence of related industries in the same geographical space. Hence, internationalization is a mechanism to access these resources that are absent domestically. While asset seeking internationalization has been identified as a mechanism for catch up, this dissertation identifies the specific technology knowledge based assets that internationalization offers and its impact on the knowledge portfolio of the internationalizing firm. Further, general catch up literature deals with small or new firms which are typically behind the technology frontier but face similar institutional conditions. This dissertation brings in the context of EEs to examine catch up in light of institutional challenges and hence provides a more fine grained understanding of the impact of internationalization on catch up.

Lastly, the dissertation contributes to the growing literature on emerging economies and firms from EEs. While most literature utilizes case based, qualitative, and single country study methodologies, this dissertation make important quantitative contributions by using a multi country, multi industry approach to contribute to the breadth of our understanding, as well as a single country, single industry approach to provide detailed insights into EE firm strategies.

Limitations

I recognize that not all patentable innovations may actually be patented. The process of application and approval of a patent is costly and time consuming. Thus it may be very expensive for the already resource constrained firms from EEs to invest the resources necessary for patent application and this may discourage some EE firms from filing for patents. However, since I only use USPTO patents for the empirical analysis, this implies that only the patents that are perceived to provide some international competitive advantage to firms are included in the sample. Since I assume that firms have made a decision on the application of a patent after careful analysis of the costs and benefits of the application process, they would only have applied for patents provided they represent significant benefits for the firm in the future.

Further, patents make some of the technology knowledge available in the public domain. Firms may not want to risk making this knowledge available and may prefer to maintain their knowledge as a secret. This may be even more applicable in the context of EEs given that the legal systems in EEs are not as strong as the ones in DEs. Thus the implementation of the protection of IP through patents may be difficult and arbitrations over patent infringement may be expensive and time consuming. Here too, the use of UPSTO patents implies that the applicants perceive value of this technology in international markets and hence choose to patent their technological developments with the USPTO.

The dissertation only focuses on new technology innovations that offer value generation for international markets, particularly markets in developed economies. I recognize that not all innovations may be patentable, especially in the case of EE markets many innovations are geared towards cost based innovations or business model innovations. The focus of examination of this dissertation is new technology based innovation. Since the USPTO is considered to be one of the important patent granting organizations worldwide and American markets value technologically sophisticated products, the patents granted by this organization naturally must be high quality patents that have been approved after a rigorous examination process. Thus the patents included in the sample represent cutting edge technology development.

The dissertation is limited in the time period of examination. I focus on patenting activities for a time period of 2000 until 2008, despite evidence of more international patenting from 2009 onwards as well. This is because I only use information on patent applications (which represent knowledge creation) and not patent grants (which represent administrative approval of the knowledge).

Opportunities for Future Research

Extending the empirical analysis from 2008 to 2016 can help provide more detailed understanding of the new technology development occurring in recent years, especially given the rapid progress of many countries and some evidence that China can now be considered a developed economy. An examination of patents filed with domestic patenting offices of individual EE countries will help provide a holistic picture of technology innovations geared towards domestic markets.

Future research can examine other aspects of technology knowledge in addition to the novelty of knowledge such as the diversity of knowledge fields and the recombination of existing knowledge into new innovations. This can provide insights into the process of new technology developments in existing knowledge fields. Future research that examines the impact of other factors such as the presence of skilled human capital and education on the novelty of technology knowledge can help identify the impact of other important input factors on technology development. Lastly, entrepreneurship has an important impact on technology development by incentivizing innovation. The examination of conditions supporting entrepreneurship in countries can help in our understanding of this phenomenon.

APPENDIX 1

MEASUREMENT OF AGE OF TECHNOLOGY KNOWLEDGE

Prior Research Measuring Age of Knowledge

Patents are a well-established measure of innovations (Griliches, 1990; Trajtenberg, 1990). However, simple patent counts do not offer depth of understanding about the value of the knowledge embedded in the patent such as the novelty or scope of the technology being patented (Trajtenberg, 1990). Patents provide detailed, publicly available information which is fairly standardized and available over long periods of time (Cohen, 1995). Much of this detailed information corresponds to the characteristic of the inventions such as information on the new technologies developed including the classes of knowledge that the patent draws from, the age of existing knowledge that it draws from (in the form of cited patents), and the inventive claims it makes, all of this in addition to the technical information captured in it.

Information on the technology classes that patents belong to has been used to identify the technology portfolio of firms (e.g. Fleming, 2001; Jaffe, 1989). Information on patent citations has been used to measure firms' innovation search activities (e.g. Rosenkopf & Nerkar, 2001; Stuart & Podolny, 1996). Research streams dedicated to the forecasting of new technologies use this information from patents to indicate the state of current technologies and forecast the evolution of technologies (e.g. Chang, Wu, & Leu, 2010; Daim, Rueda, Martin, & Gerdsri, 2006; Mogee, 1991).

Patent citations are valuable sources of information. Forward citations have been used as measures of the importance and value of innovations (e.g. Trajtenberg, 1990). Backward citations provide information about the existing knowledge that organizations search for and build on in order to develop new innovations. Different aspects of knowledge such as knowledge scope and knowledge depth have been measured using information from cited patents (Katila, 2002). For example, Bierly and Chakrabarti (1996) and Rosenkopf and Nerkar (2001) use the age of patents that are cited by firms' focal patents to measure knowledge search and its impact on innovativeness. Katila (2002) uses the average age of patent citations as a measure of the type of knowledge that firms search for in order to develop innovations.

Mean Age of Technology Knowledge

Mean age of knowledge is the key dependent variable of examination in this dissertation. This variable measures the age of the knowledge of patents from a country or a firm for a given year. This is done by using information on the age of citations that the focal patents in the sample cite as their source of knowledge.

To develop this measure, I carried out the following steps. First, for each cited patent, I calculated the difference between the date of the filing of the focal patent and the date of grant of the cited patents. The date of filing of the focal patent is indicative of the time that the knowledge continued in the patent was first generated. The date of grant of the cited patent is indicative of the time that the knowledge contained in the cited patent was verified as novel by the patenting office and was made available for use to others. Second, I computed the mean age of all the cited patents corresponding to each focal patent. This number is the mean age of knowledge that each focal patent cited. Third, I calculated the mean of the age of all focal patents (from step 2) granted to a country for a given year. The resulting number is the mean age of technology knowledge at a country year level. This represents the mean age of knowledge that a country's patents cite in their patent applications for a given year. Table A1.1 presents an example of these steps in a tabular format with the computations.

Table A1.1 Example of Mean Age Variable Calculation

Coun-try Name	Country Number	Year	Patent ID	Focal Patent No	Focal Patent App. Date	Cited Patent No	Cited Patent Grant Date	Cited Patent Age (Days)	Mean Age of all Cited Patents for Each Focal Patent	Mean Age of all Focal Patents for a Country-Year
A	1	2000	1	111111	1/1/1999	999999	1/1/1998	365		
A	1	2000	1	111111	1/1/1999	999998	1/1/1997	730		
A	1	2000	1	111111	1/1/1999	999997	1/1/1996	1095		
									730	
A	1	2000	2	111112	1/1/1998	555551	1/1/1988	3650		
A	1	2000	2	111112	1/1/1998	555552	1/1/1978	7300		
									5475	
A	1	2000	3	111113	1/1/1997	222222	1/1/1996	365		
									365	
A	1	2000								2190
A	1	2001	4	211111	1/1/1999	666666	1/1/1980	6935		
A	1	2001	4	211111	1/1/1999	666667	1/1/1985	5110		
									6022.5	
A	1	2001	5	211112	1/1/1996	666666	1/1/1980	5840		
A	1	2001	5	211112	1/1/1996	444444	1/1/1995	4015		
									4927.5	
A	1	2001								5475

With respect to the firm level study, the same steps were carried out, by using information on the patents assigned to individual firms that were included in the sample. First, for each cited patent, I calculated the difference between the year of the filing of the focal patent and the year of grant of the cited patents. Second, I computed the mean age of all the cited patents corresponding to each focal patent. Third, I calculated the mean of the age of all focal patents granted to a given firm for a given year. The resulting number is the mean age of technology knowledge at the firm-year level. This represents the mean age of knowledge that a firm's patents cite in their patent applications for a given year.

Descriptive Statistics

Table A1.2 consists of the summary statistics of the variable. As we can see the data are overdispersed with the mean (3843.034) being much lower than the variance (1123086). The age of knowledge values range from around 900 days (about 2-3 years) to 7000 days (19 years) with a mean of 3843 days and standard deviation of 1060 days.

Table A1.2 Summary Statistics of Mean Age of Knowledge

		Percentiles	Percentiles	Smallest	Largest
Obs	432	1%	1582.094	920.5423	6331.879
Mean	3843.034	5%	2089.495	1251.734	6532.88
Std. Dev.	1059.758	10%	2353.466	1301.276	6648.316
Variance	1123086	25%	3099.64	1480.003	7005.997
Skewness	-0.0501964	50%	3892.399		
Kurtosis	2.673168	75%	4612.67		
		90%	5167.51		
		95%	5550.308		
		99%	6293.866		

Table A1.3 presents the skewness test for the variable. Here we see that we cannot reject the hypothesis that mean age of knowledge variable is normally distributed.

Table A1.3 Skewness/Kurtosis Test for Normality

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2
Mean Age of Knowledge	432	0.6652	0.1293	2.49	0.2872

Figure A1.1 presents a histogram of the distribution of the mean age variable at the country year level.

Figure A1.1: Histogram of Mean Age of Knowledge

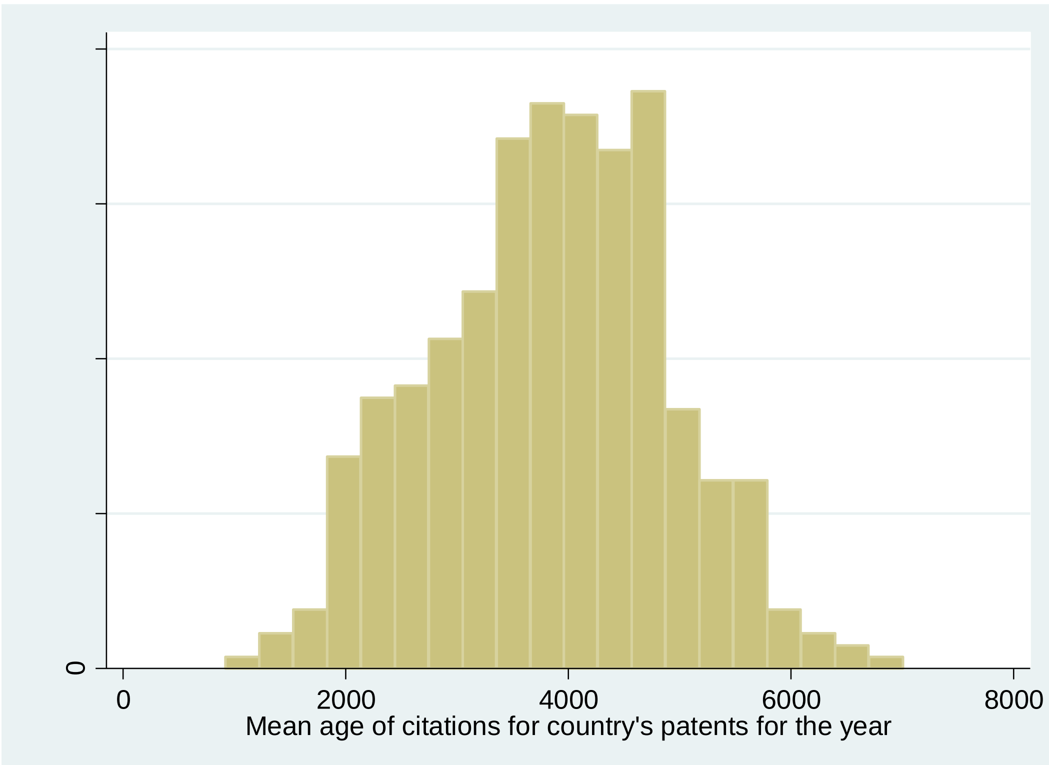


Figure A1.2 presents two histgrams of the age variable broken down into developed and developing countries. The graph to the left represents the distribution for developing countries, whereas the one to the right represents the distribution for developed countries. As we can see the mean age values are less dispersed for developed countries in comparison to developing countries.

Figure A1.2 Histogram of Mean Age of Knowledge by Country Category

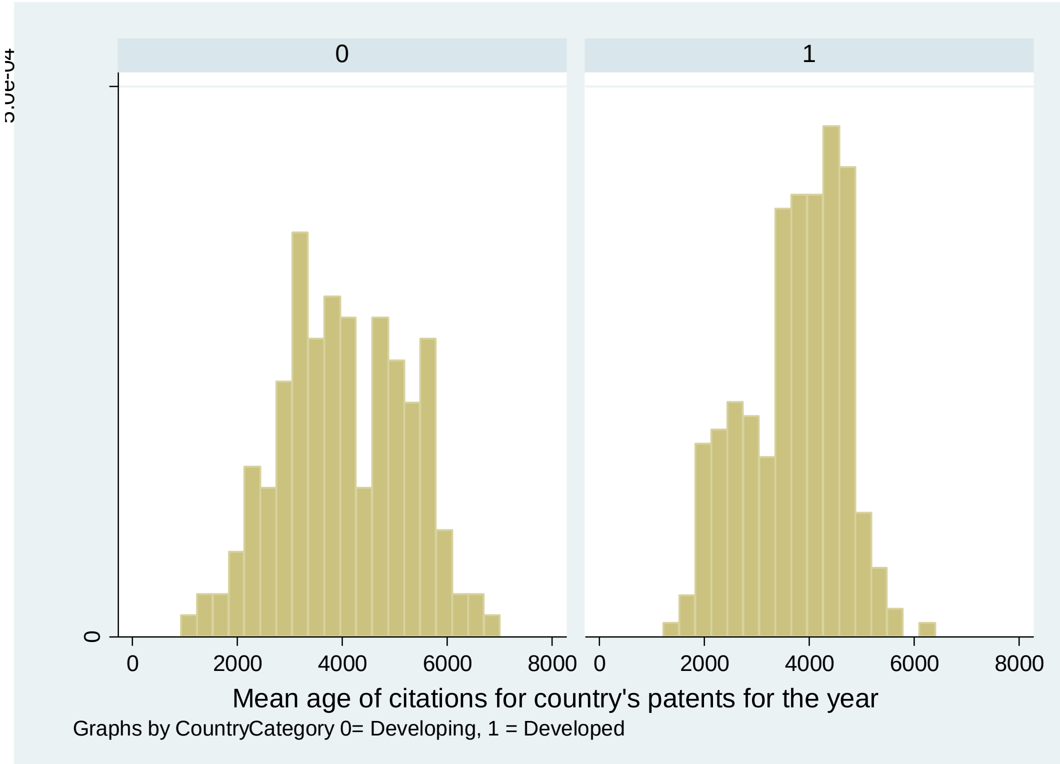
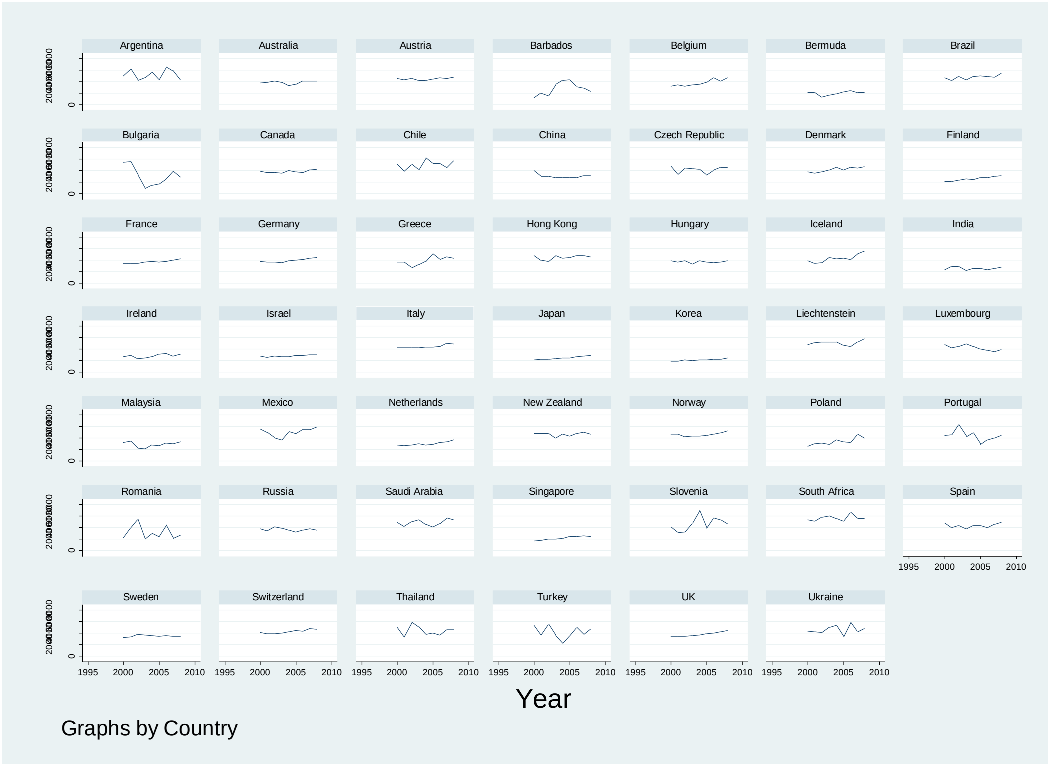


Figure A1.3 represents the mean age values over the years for the individual countries in the sample. We can see significant variation in the age values over the years for certain countries (e.g., Argentina, Chile, Portugal etc.), whereas others show lesser variation (e.g., Canada, Germany, Sweden etc.).

Figure A1.3 Mean Age over the Years for Individual Countries



Additional Measures of Knowledge

In addition to the mean age measure described above I also developed additional measures for measuring the types of knowledge being patented. Literature examining technological diversification suggests that higher variation in the technological efforts can lead to more valuable innovations (Fleming, 2001). Thus, examining the diversity in EEs's technological efforts can lead to better understanding of the phenomenon of innovation in EEs. Prior research has used information on the technology classes that patents are assigned in order to identify the technology portfolio of firms (e.g. Fleming, 2001; Jaffe, 1989). For example, Lerner (1994) measures the economic value of patents in the form of patent scope by utilizing information on the number of unique classes that patents belong to. Fleming (2001), measures the technological diversification of firms using the number of different technology classes that their patents belong to. Katila (2002) measures the number of new technology classes that firms enter as a proportion of their existing classes each year to examine the depth of their knowledge.

I develop additional measures based on patents' IPC classification in order to examine the diversity of technological efforts of EEs. In order to develop these measures, I used information on the different patent classes and subclasses that the patents in my sample belong to using the International Patent Classification (IPC) published by the World Intellectual Property Organization (WIPO). Every patent belongs to a number of different sections, classes, and subclasses assigned by the patent granting office (in this case the US Patent and Trademark Office). The patent classes correspond to the underlying technological foundations that the patent builds on.

Applicants for the patents may suggest the technical classifications applicable to their application, but patent examiners who work with the USPTO are the ultimate arbiters of class assignments. In addition, applications are filed through experienced patent attorneys, who make these suggestions for the appropriate classes for a given patent. Hence, the use of such specialists (i.e., patent attorneys and examiners), in addition to the thorough examination that each patent is subject to before being granted minimizes risks of misclassification of patents and ensures absence of errors due to misclassification (Sampson, 2007).

Below is an example that illustrates the IPC classification and its different tiers. Considering that patent number 999999 has the following classes assigned to it H01N 33/483, H01N 33/487, and H01S 3/09, the classification corresponds to the following characteristics of technology.

Section – Each patent belongs to sections designated by one of the capital letters A through H.

Example: H

The eight sections are entitled as follows:

A Human Necessities

B Performing Operations; Transporting

C Chemistry; Metallurgy

D Textiles; Paper

E Fixed Constructions

F Mechanical Engineering; Lighting; Heating; Weapons; Blasting

G Physics

H Electricity

Each section is then subdivided into classes which are the second hierarchical level of the classification.

Class Symbol – Each class symbol consists of the section symbol followed by a two-digit number. *Example: H01*

Class Title – The class title gives an indication of the content of the class. *Example: H01 BASIC ELECTRIC ELEMENTS*

Each class further comprises one or more subclasses which are the third hierarchical level of the classification.

Subclass Symbol – Each subclass symbol consists of the class symbol followed by a capital letter. *Example: H01S*

Subclass Title – The subclass title indicates as precisely as possible the content of the subclass. *Example: H01S DEVICES USING STIMULATED EMISSION*

Table A1.4 presents details about the classification. The WIPO provides the following information about the number of categories belonging to each tier.

Table A1.4 IPC Classification

Section	No. of classes	No. of subclasses	No. of main groups	No. of subgroups	Total no. of groups
A	16	84	1132	7763	8895
B	38	169	1992	14930	16922
C	21	87	1321	13187	14508
D	9	39	350	2700	3050
E	8	31	323	3115	3438
F	18	97	1072	7705	8777
G	14	81	696	7426	8122
H	6	51	548	8326	8874
Total	130	639	7434	65152	72586

Using this information about patents' IPC classification I created the following measures.

Mean Number of Technology Classes

This variable measures the mean number of IPC subclasses that patents from a country belong to for a given year. This is done by using information on the IPC classification presented above. To develop this measure, I carried out the following steps. First, for each patent, I obtained the number of unique IPC subclasses that each patent belongs to. Second, I calculated the mean number of IPC subclasses for all patents granted to a country for a given year. The resulting number is the mean number of technology classes at a country-year level. Table A1.5 describes the calculation with an example.

Table A1.5 Calculation of Mean Number of Technology Classes

Country Name	Country Number	Year	Patent No.	IPC of patent	Unique 4-digit Subclasses	Patent Count	Mean No of Technology Classes at Country-Year Level
A	1	2000	111111	G01N 33/483	1		
A	1	2000	111111	G01N 33/487	0		
A	1	2000	111111	H01S 3/09	1		
A	1	2000	111112	G01N 33/49	1		
A	1	2000	111112	H01F 1/032	1		
A	1	2000	111113	H01S 3/094	1		
					5	3	1.7
A	1	2001	211111	H01F 1/032	1		
A	1	2001	211111	H01F 1/032	0		
A	1	2001	211112	H01F 1/032	1		
A	1	2001	211112	H01S 3/094	1		
					3	2	1.5

Descriptive Statistics

Table A1.6 presents the descriptive statistics for the above variable. As we can see a country's patents for a given year belong to 2.36 unique subclasses for a given year. Their values range from a minimum of 1 to a maximum of about 15 with a variance of 4.4.

Table A1.6 Summary Statistics for Mean No. of Technology Classes

		Percentiles	Percentiles	Smallest	Largest
Obs	432	1%	1	1	12.18994
Mean	2.363627	5%	1.090909	1	13.52797
Std. Dev.	2.098591	10%	1.163934	1	13.73333
Variance	4.404084	25%	1.314884	1	15.06294
Skewness	3.216772	50%	1.584408		
Kurtosis	14.68718	75%	2.482652		
		90%	4.505655		
		95%	6.744094		
		99%	12		

Count of IPCs

These variables measure the total number of IPC sections, classes, and subclasses that a country's patents belong to for a given year. They are discussed below.

Country_section_ct: This variable represents the annual total number of IPC sections a given country was present in across all patents.

Country_class_ct: This variable represents the annual total number of IPC classes given country was present in across all patents.

Country_subclass_ct: This variable represents the annual total number of IPC subclasses given country was present in across all patents.

Weighted Counts of IPCs

Weighted counts are calculated as follows. Each time a given IPC appears, it is divided by the number of other IPCs that tend to appear with it on a patent (based upon all patents filed that year). For example, if on average IPC 'X' appears with 2 other patents (2+1=3), then the weighted count is the times X appears divided by the average (say 3). This number is then divided by the patent count for that country-year.

weightedIPCsectPat: This variable represents the annual weighted sum of IPC sections divided by number of patents for a given country.

weightedIPCclassPat: This variable represents the annual weighted sum of IPC classes divided by number of patents for a given country.

weightedIPCpatent: This variable represents the annual weighted sum of IPC subclasses divided by number of patents for a given country.

Entropy of IPC measures

Entropy measures are the total diversification across different IPC definitions. They are based upon the number of times an IPC category is observed divided by the total times all IPC categories are observed. This is the "alpha". The formula (alpha*ln(alpha) is then summed over the observations.

Entropy_IPCsection: This variable represents the annual entropy across IPC sections for a given country.

Entropy_IPCclass: This variable represents the annual entropy across IPC classes for a given country.

Entropy_IPC: This variable represents the annual entropy across IPC subclasses for a given country.

Herfindahl Index of IPCs

This measure is similar to the entropy definition, but the formula is (alpha^2).

Herf_IPCsection: This variable represents the annual Herfindal index across IPC sections for a given country.

Herf_IPCclass: This variable represents the annual Herfindal across IPC classes for a given country.

Herf_IPC: This variable represents the annual Herfindal across IPC subclasses for a given country.

Below are examples of the calculation of all of the above variables.

Example 1: For example, Country A has the following patents

111111: with IPC: G01N 33/483, G01N 33/487, and H01S 3/09

111112: with IPC: G01N 33/49, and H01F 1/032

111113: with IPC: H01S 3/094

Patentcount = 3

Country_section_ct = 2 (G & H)

Country_class_ct = 2 (G01 H01)

Country_subclass_ct = 3 (G01N H01S H01F)

Weighted counts

The weighted count measures depends upon the population means, but let's say the measures for they are 1.5 (for G) and 2 (for H) then the weighted count would be: { 1/1.5 + 1/2 (first patent) + 1/1.5 + 1/2 (second patent) + 1/2 (third patent)}/number of patents = 2.833/3 = 0.9444

Entropy

For the section level: The data becomes G&H, G&H, G (for the three patents). This is a total of 5 counts of unique sections across the patents. The calculation would be

3/5ln(3/5)+2/5ln2/5 = .6*-0.511 + .4*-0.9163 = -0.3065+(-0.3666) =0.6731

Example 2: Country B has the following patents

9350394: with IPC: H04B 1/40, H04B 1/04, H01Q 5/335, H01Q 9/14, and H04B 1/18

9349288: with IPC: G08G 1/8; G08G 1/01; G08G 1/052

9344616: IPC: G08B 21/00; H04N 5/232; H04N 7/18; G08B 13/196; H04N 5/247; G06F 3/06

9344616: with IPC: H04L 12/58; G06F 17/30; H04L 29/08; H04W 4/08

Patentcount = 4

Country_section_ct = 2 (H&G)

Country_class_ct= 4 (H04, H01, G08, G06)

Country_subclass_ct = 8 (H04B H01Q G08G H04N G08B G06F H04L H04W)

Weighted counts

The weighted count measures depends upon the population means, but let's say the measures for they are 1.5 (for G) and 2 (for H) then the weighted would be:

{ 1/1.5 (first patent) + 1/2 (second patent) + 1/1.5 + 1/2 (third patent) +1/1.5 + 1/2 (fourth patent)}/number of patents = {0.66+0.5+0.66+0.5+0.66+0.5}/4 =3.5/4 = 0.875. This suggests that while Country B is in the same number of sections as Country A, Country A has a higher weighted average because it achieved those sections with fewer patents.

Entropy

For the section level: The data becomes H, G, G&H, G&H (for the four patents). This is a total of 6 counts of unique sections across the patents. The calculation would be

3/6ln(3/6) + 3/6(ln(3/6)= 0.5*-0.6931+0.5*-0.6931= 0.6931 While close, Country B is a bit more diverse than country A. Country A is focused more on IPC section G (3 to 2) while Country B is equally spread out between G&H.

Descriptive Statistics for Additional Variables

Table A1.7 presents the summary statistics for these additional variables. As we can see, depending on the type of IPC categorization we pick (either section, class, or subclass) we see more variation in the count variables. The weighted count measures, entropy measures, and Herfindahl measures seem to alleviate some of these problems associated with a simple count measure.

Table A1.7 Summary Statistics for Additional Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
country_section_ct	432	7.578704	1.208366	4	16
country_class_ct	432	63.11111	37.81297	7	183
country_subclass_ct	432	183.4028	160.6512	11	785
weightedIPC_sect_pat	432	1.075533	0.087274	0.823115	1.513569
weightedIPC_class_pat	432	0.917488	0.064213	0.696383	1.304317
weightedIPC_pat	432	0.792447	0.05395	0.589807	1.041483
entropy_IPC_section	432	-1.69865	0.196184	-1.9631	-0.73947
entropy_IPC_class	432	-3.15755	0.49558	-4.05722	-1.07973
entropy_IPC	432	-4.10899	0.753421	-5.44701	-1.21303
herf_IPC_section	432	0.218568	0.064437	0.147716	0.613226
herf_IPC_class	432	0.078618	0.052921	0.025934	0.548077
herf_IPC	432	0.038488	0.043158	0.007304	0.54142

I utilize the mean number of technology classes measure as an alternative measure to test for the robustness of my main findings. The results from this analysis are presented in detail in Appendix 2.

APPENDIX 2

METHODOLOGY & ROBUSTNESS CHECKS FOR COUNTRY LEVEL STUDY

Introduction to Methodology

This study examines the impact of the level of institutional development and global connectedness on the age of technologies that countries patent in. To do this I develop a panel data set of the patenting activities of the countries in my sample. Traditionally most panel data analysis involves the use of fixed effects or random effects estimation models. However, the endogeneity issues associated with the use of these models are alleviated by the use of dynamic panel data models such as the Arellano Bond model. This model involves the use of lagged values of the dependent variable as instruments for the dependent variable and uses a generalized method of moments (GMM) estimation using these variables. Further, the use of the Arellano–Bover/Blundell–Bond correction takes into account the presence of autocorrelated errors and hence resolves the problem of autocorrelation.

Fixed and Random Effects Models for Panel Data Analysis

The dataset utilized for this study is a panel data set with multiple observations over multiple years for the countries that are in the sample. Specifically this panel dataset consists of a large number of countries which are observed for small number of time periods, which is typical for much economic data. Most econometric models for panel data analysis use either fixed effects or random effects models. Fixed effects estimators treat the independent variables as non-random and assume individual (in this case country) specific, time invariant effects. Random effects models on the other hand assume that the independent variables arise from random causes. However, these static panel data models may provide inconsistent estimates due to the presence of endogenous independent variables. The use of dynamic panel data models helps alleviate this problem by including lagged terms of the dependent variable in the model.

The unobserved heterogeneity in these models can be resolved by differencing i.e. by taking first differences in order to remove the time invariant components from the model. However sometimes this is problematic, especially in the case of dynamic panel data. This is because the process which subtracts the individual's mean value of y and each X from the respective variable creates a correlation between the independent variable and the error (Nickell, 1981). This correlation creates a bias in the estimate of the coefficient of the lagged dependent variable. This problem is not resolved by increasing N i.e. the number of individuals (countries in this case). It is also not resolved by including additional independent variables in the model. In addition, if the independent variables are correlated with the lagged dependent variable to some degree, it causes their coefficients to be biased as well (Nickell, 1981). The use of random effects models leads to similar issues. Thus, since the lagged dependent variable is not independent of the error and can lead to biased estimates other estimation models need to be used.

Anderson–Hsiao Instrumental Variable Estimation

One way to resolve this problem is to take first differences of the original model. This model was presented by Anderson and Hsiao (1980) and is called the Anderson–Hsiao estimator. It can be explained as follows. For example, the following model contains a lagged dependent variable and a single independent variable:

$$y_{it} = \beta_1 + \rho_{yi,t-1} + X_{it}\beta_2 + u_i + €_{it}$$

The first difference transformation removes both the constant term and the individual effect as follows

$$\Delta y_{it} = \rho\Delta y_{i,t-1} + \Delta X_{it}\beta_2 + \Delta €_{it}$$

The removal of these effects makes an instrumental variables estimator available. Using the second and third lags of y instrumental variables can be created for the lagged dependent variable. However, this model is considered to be inefficient since it does not utilize all the information available in the sample (Arellano & Bond, 1991). The use of a Generalized Method of Moments (GMM) model may help to create more efficient estimates.

Arellano and Bond Estimation

The Arellano-Bond estimator helps to resolve the issues identified above. This can be explained through the following example. The following model consists of X as the exogenous independent variable, W as the lagged value of y, and u as the unobserved individual effect.

$y_{it} = X_{it}\beta_1 + W_{it}\beta_2 + u_i + €_{it}$

First-differencing the equation removes the u and its associated bias. This estimator can be used to construct moments conditions and use the GMM estimation. The model is specified as a system of equations where the instruments applicable to each equation are different for each time period. These instruments are based on the lagged values from the prior equation. For example, depending on the number of time periods available in the panel additional lagged values of the instruments are available for later time periods.

The Arellano Bond estimation is useful for panels with few time periods (T) and many individuals (N) observed in the panel. It is useful for models involving independent variables that are not strictly exogenous. These variables may be correlated with the error term as also the prior of themselves and so the use of this model alleviates issues of endogeneity. This model also corrects for heteroskedasticity and autocorrelation within individuals.

Arellano-Bover/Blundell-Bond System Estimation

A problem with the use of the Arellano Bond estimator is that the multiple lagged levels described above are weak instruments for the first differenced variables in case of persistent autocorrelation (Blundell & Bond, 1998). The Arellano and Bover/Blundell and Bond system estimator resolves this issue of autocorrelated errors (Arellano & Bover, 1995; Blundell & Bond, 1998). This estimator includes additional moment conditions in which lagged differences of the dependent variable are orthogonal to the errors.

Robustness Checks

I use the mean number of technology classes variable (described in Appendix 1) as the dependent variable to check the robustness of my empirical findings. Table A2.1 presents the pairwise correlations of this variable with the other variables used for analysis. As we can see the mean number of classes that a country's patents belong to has a slight positive correlation with the level of imports and the regulatory quality of the country.

Table A2.1 Pairwise Correlations

	1	2	3	4	5	6	7	8	9
Mean No. of Tech Classes	1								
Imports	0.0095	1							
Regulatory Quality	0.2156	0.0685	1						
GDP	0.3214	0.0048	0.6575	1					
Number of LLCs	0.0239	0.1023	0.1032	-0.006	1				
FDI Inflows	0.2059	0.2323	0.1495	0.1329	0.3269	1			
R&D Expenditure	0.1473	0.1238	0.4832	0.5442	-0.0869	0.0884	1		
Population	-0.0655	0.078	-0.4496	-0.287	0.0472	0.1358	-0.1447	1	
Country Category	0.204	0.1072	0.7324	0.7168	0.1031	0.147	0.6229	-0.2975	1

Table A2.2 presents the regression results using the dependent variable mean number of technology classes. The first row of results represents the regression coefficients of the lagged value of the dependent variable. The data do not support the hypotheses.

Table A2.2 Regression Results

DV: Mean No. of Tech Classes	**Model - Controls**	**Model H3A Global Connectedness**	**Model H3B Institutional Development**
Mean Tech Classes Lag	0.799***	0.764***	0.781***
	(9.19)	(8.76)	(8.78)
Imports		2.961	
		(1.88)	
Regulatory Quality			-1.649
			(-1.19)
GDP	-1.2	-1.835	1.595
	(-0.37)	(-0.57)	(0.40)
Number of LLCs	0.0218*	0.0187	0.0241*
	(2.19)	(1.88)	(2.37)
FDI Inflows	4.79E-12	3.52E-12	4.48E-12
	(1.70)	(1.25)	(1.57)
R&D Expenditure	3.701**	3.405**	4.104***
	(3.15)	(2.93)	(3.36)
Population	-10.98	-19.99	-10.02
	(-1.05)	(-1.76)	(-0.94)
Country Category	-2.77	-2.635	-2.679
	(-1.72)	(-1.67)	(-1.65)
Constant	-2.914	-2.094	-2.744
	(-1.52)	(-1.08)	(-1.41)
N	224	224	224

APPENDIX 3

METHODOLOGY & ROBUSTNESS CHECKS FOR FIRM LEVEL STUDY

Introduction to Methodology

This study examines the impact of firms' level of internationalization on the age of technologies that they patent in. I test my hypotheses in the context of biopharmaceutical firms from India. To examine the knowledge portfolio of firms, I use data on all patents filed by these firms with the USPTO and develop measures of the age of the knowledge that these patents build on. I develop a panel of firm level data over the years and use a zero inflated negative binomial regression model to test my hypotheses. Below are details about the model selection.

Count Data Analysis: Poisson or Negative Binomial Models

The dependent variable of examination is the age of technology knowledge at the firm year level. It is measured by computing the mean age of the patents that a firm cites in its patents (a detailed discussion of the measure is presented in Appendix 1). The unit in which the age of knowledge is recorded is years. This number cannot be negative and so the dependent variable is a discrete, non-negative, count variable. Linear regression models are not suited for estimating count data since they do not take into account the fact that the dependent variable can only take on a limited set of values. Regression models that are appropriate for use with such count data are Poisson or negative binomial models. Poisson models are useful for modelling data that follow a Poisson distribution.

The probability density function of the Poisson distribution where e is the base of the natural logarithms and y! is the factorial of y is as follows:

$$\Pr(Y = y) = (e^{-\mu} \mu^{y} / y!) , y=0,1,2,. . ..$$

The Poisson model is estimated using maximum likelihood estimation which is as follows:

$$\sum_{i=1}^{N} (y_i - \exp(x_i \beta))x_i = 0$$

One limitation associated with this model is that the Poisson distribution assumes that the mean and variance of the variable are equal. If this assumption is violated, the use of a Poisson model might bias the estimates. In the case of the data in question, the variance of the sample exceeds the mean. This indicates that the data are over dispersed. Thus, in this situation the negative binomial model is preferred over the Poisson model.

Negative Binomial Model

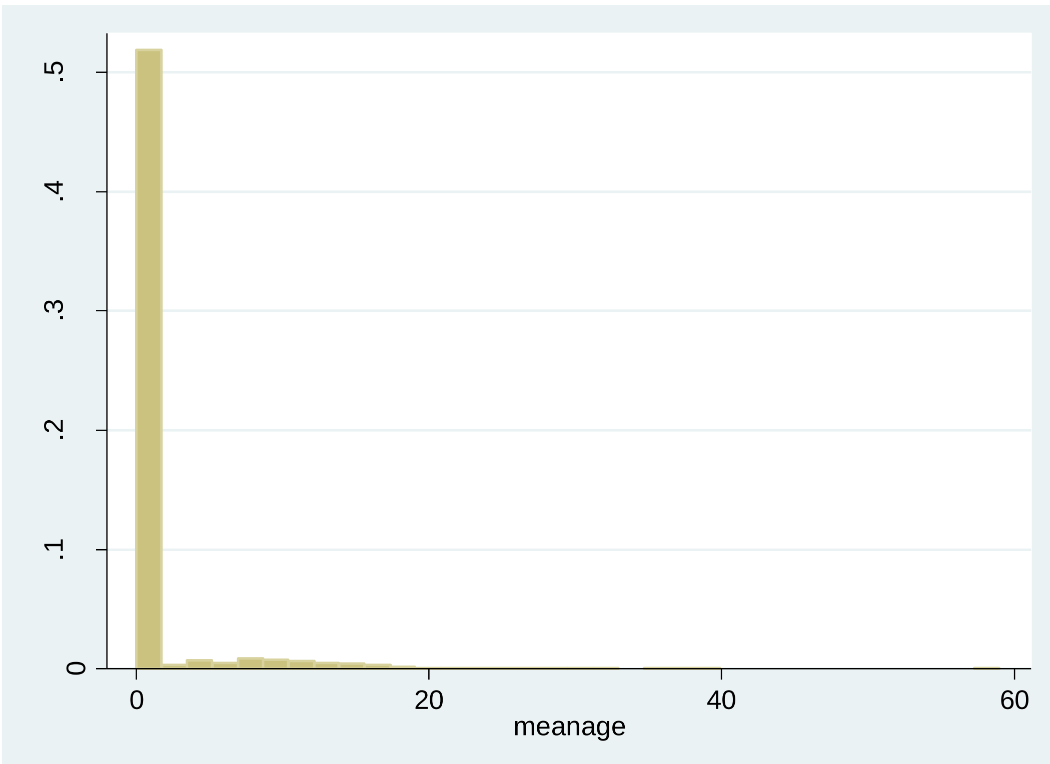
The negative binomial distribution consists of an additional parameter as compared to the Poisson distribution i.e. it is a two parameter distribution. While the Poisson distribution is fully characterized only by its mean μ, the negative binomial distribution is a function of both μ and α. Thus it includes both the Poisson distribution and the Gamma distribution. This adjusts the variance of the data independently from the mean. This overcomes the issues associated with the use of Poisson models for examining overdispersed data.

Zero inflated Negative Binomial Model

Sometimes count data contain excessive number of zeros and actual occurrences of a non-zero count observation are low. This may be because two kinds of zeros may exist in the data, "true zeros" and excess zeros. The first kind of zero arises from the absence of any observations of the variable and the second kind of zero arises from the absence of the occurrence of phenomenon or activity that precedes the said observation. This means that the zero value recorded in the data is caused by two different processes and needs to be estimated differently.

In the case of my examination, the data show a large number of zeros since there are many firms which have no patents for the period of examination. However, many of these firms do carry out R&D. This means that there are a number of firms that perform R&D but are unable to or choose not to translate their R&D into patentable knowledge. Further, there are also firms that do not engage in any R&D and consequently have no patents. Accordingly, the data are zero inflated and hence I use the zero inflated negative binomial model for testing my hypotheses. Figure A3.1 shows a histogram of the distribution of the knowledge age variable.

Figure A3.1: Histogram of Mean Age of Knowledge



A zero-inflated model attempts to account for these excess zeros in the data. This is done by estimating two equations, one for the count model and another for the binary model. The binary model is generally a logit model which models one of the two processes that lead to the zero observation. In this case, that process refers to either engaging in R&D investments or not.

The count model then models the count process. In this case it refers to the number of innovations that were generated by firms actually engaging in R&D.

The expected count is thus expressed as a combination of the both of the above two processes. It can be summarized as follows:

E(Age of knowledge) = prob(no R&D activity)*0 + prob(R&D activity)*E(y=k| R&D activity)

Thus, the estimation using the zero-inflated negative binomial model requires the specification of variables that will influence the binary outcome. In this case, the appropriate variable is the R&D intensity of the firm.

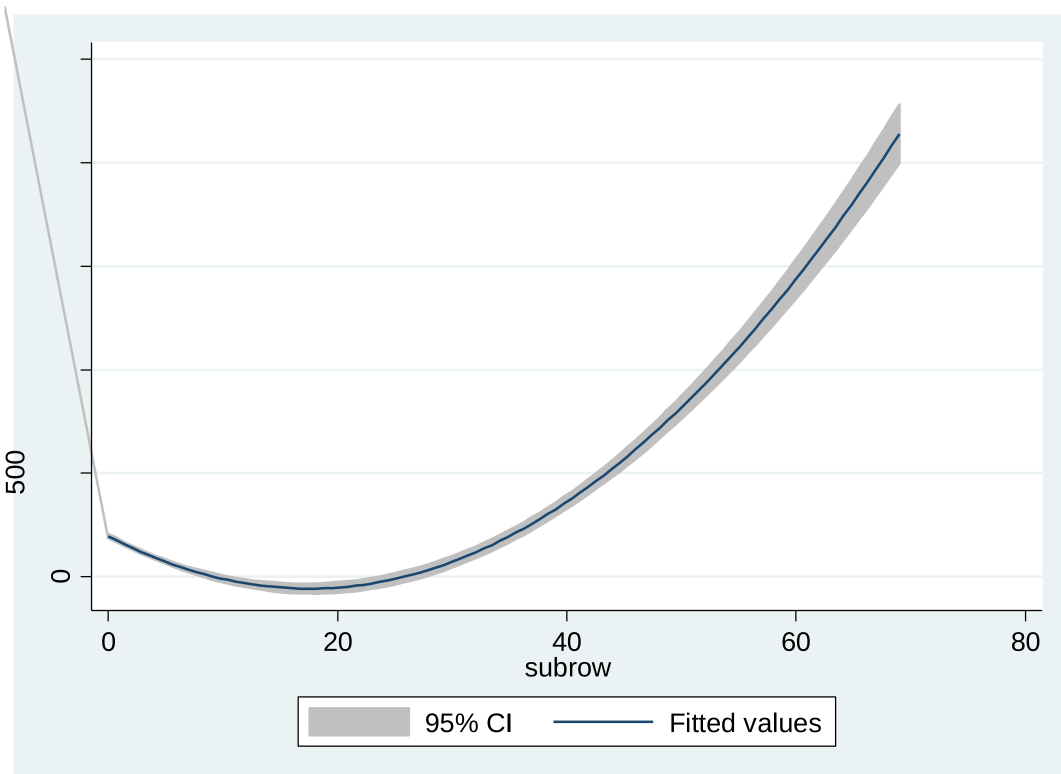
I also perform the Vuong test (Vuong, 1989) to further test the appropriateness of zero inflated negative binomial versus negative binomial model. The Vuong test compares the zero-inflated model negative binomial with an ordinary negative binomial regression model. A significant z-test indicates that the zero-inflated model is preferred. I find that the negative binomial model specification is rejected. Thus, I test the hypotheses using zero inflated negative binomial analysis (ZINB in STATA) where the dependent variable is the mean age of a firm's technology knowledge.

Robustness Checks

In order to test for U shaped relationships, research suggests various ways to ensure appropriate model specification. One way is to include the first order independent variable in the regression (Aiken & West, 1991), the coefficient of which was negative and statistically significant in this case. I then build upon the three step procedure developed by Lind and Mehlum (2010) that helps establish a quadratic relationship. First, the significant and negative coefficient for the linear term and the significant and positive coefficient for the squared term indicate the presence of a quadratic relationship.

Second, I calculate the turning point of the equation and make sure that it is well within the data range and not positioned towards the extreme as that would indicate the curvilinear relationship being driven by outliers. Figure A3.2 shows the curve of the predicted age values and the 95% confidence intervals using the regression estimates.

Figure A3.2 Predicted values of dependent variable 95% confidence interval



Lastly, I split the data based on the median internationalization value following Qian et al. (2010) and run separate regressions for both sub samples. The regression using the low internationalization sub sample indicates a negative and significant relationship between internationalization and age whereas the regression using the high internationalization sub sample produced non-significant results.

Further, I also add an additional control variable to the analysis. I control for the field of knowledge that the firms primarily work on. Since some firms are engaged in generic manufacturing of drugs whereas others are engaged in the development of new active pharmaceutical ingredients (APIs), these different types of firms may focus their technological efforts in different areas. Accordingly, I collect information on whether firms are engaged in only generics or APIs as well. I create a dummy variable of firms engaged in API research and include that in the analysis. Table A3.1 presents the regression results from this analysis. As we can see the data fail to support the hypotheses.

Table A3.1 Regression Results

	Model 1 Controls	Model 2 H1A	Model 3 H1B	Model 4 H1C
LevelofGlobalization		-0.00884	-0.0102	-0.0126
		(-1.68)	(-0.75)	(-0.53)
LevelofGlobalsquared			0.000031	0.000196
			(0.11)	(0.14)
LevelofGlobalcubed				-0.0000026
				(-0.12)
Patents	-0.0114	-0.0173	-0.0175	-0.0176
	(-0.96)	(-1.40)	(-1.40)	(-1.41)
IndianPatents	-0.00403	-0.00584	-0.00606	-0.00623
	(-0.46)	(-0.67)	(-0.68)	(-0.69)
TotalAssets	0.0000242	0.000169	0.000166	0.00017
	(0.14)	(0.90)	(0.87)	(0.88)
Firm Age	0.00629*	0.00555	0.00556	0.00559
	(2.22)	(1.95)	(1.95)	(1.95)
TobinsQ	0.00552	0.00423	0.00433	0.00452
	(0.15)	(0.12)	(0.12)	(0.13)
TotalExports	-0.0000172	-0.0000267	-0.0000174	-0.0000276
	(-0.04)	(-0.06)	(-0.04)	(-0.06)
RDLabsForeign	-0.0222	0.0585	0.0613	0.0567
	(-0.33)	(0.71)	(0.71)	(0.60)
Alliances	-0.0372	-0.0289	-0.0292	-0.0288
	(-0.76)	(-0.59)	(-0.60)	(-0.59)
API	0.00718	0.00134	0.00127	0.00217
	(0.07)	(0.01)	(0.01)	(0.02)
Constant	2.249***	2.292***	2.298***	2.302***
	(14.86)	(15.09)	(14.17)	(13.97)
inflate				
RDintensity	-32.90***	-32.92***	-32.92***	-32.91***
	(-5.69)	(-5.69)	(-5.69)	(-5.69)
Constant	1.219***	1.220***	1.219***	1.219***
	(4.95)	(4.95)	(4.95)	(4.95)
lnalpha				
Constant	-1.941***	-1.976***	-1.976***	-1.977***
	(-9.16)	(-9.18)	(-9.18)	(-9.18)
N	119	119	119	119

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