NON-RESIDENT PATENTING: ITS DETERMINANTS AND IMPACT ON THE HOST COUNTRY

Ph.D. Thesis

By
APARNA SHARMA

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APARNA SHARMA

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **NON-RESIDENT PATENTING: ITS DETERMINANTS AND IMPACT ON THE HOST COUNTRY** in the partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** and submitted in the **DISCIPLINE OF ECONOMICS, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from July 2016 to April 2023 under the supervision of Dr. Ruchi Sharma, Professor, School of Humanities and Social Sciences (HSS), Indian Institute of Technology Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

4 MAY 2023

(APARNA SHARMA)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

4 MAY 2023 Ruchi Sharma

(Dr. RUCHI SHARMA)

APARNA SHARMA has successfully given his/her Ph.D. Oral Examination held on **<Date of PhD Oral Examination>**.

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Dedicated to my beloved

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SYNOPSIS

Introduction

Non-resident patent, an application filed with a patent office of a country/jurisdiction by a resident of another country/jurisdiction, is an important aspect of international technology transfer (WIPO, 2023). In an interconnected global economy, the number of patent applications filed worldwide increased from 959,764 in 2001 to 3,330,000 in 2019, representing a growth of approximately 247% (WIPO, 2020). This significant increase can be attributed to the globalization of the world economy, the rise of emerging markets, and the advancement of technology. During this period the geographic distribution of patent filings has also been changed. In 2001, most of the patent applications came from developed countries such as the United States (the US), Japan, and European countries (Germany, France etc.). However, in recent years, there has been a significant increase in patent applications filed in and by emerging economies, such as China, Korea, and India.

This thesis explores the concept of non-resident patenting and its determinants and importance. Previous literature has highlighted the importance of foreign patenting for protecting intellectual property, expanding business operations, creating licensing opportunities, and providing a defensive tool against potential litigation. While there are challenges associated with foreign patenting, it remains a critical tool for businesses seeking to compete and succeed in a globalised economy.

The emergent research on this topic has revealed that the exploitation of foreign countries' patent systems by innovators for the commercialization of technology invented in their home country is an important factor for innovation and national economic development (Willoughby & Mullina, 2021). The questions that remain unanswered, however, are what is the role of technological capabilities of the host and home countries in determining non-resident patents and what are the different channels through which host country gain from such patents? Based on this discussion, the objectives of this dissertation are:

1. To investigate the role of technological capabilities of patent source country and technology gap between the patent source and destination countries in inducing the cross-country patenting activity.
2. To explore the influence of non-resident patents on R&D investment of the host countries.
3. To examine the impact of international patents on the resident patents of the host country.
4. To study the non-resident patenting as an important driver of Total Factor Productivity (TFP) of the host country.

Literature Review

Micro Econometric Perspective of International Patenting: Understanding Firm Level Motivations

From a micro econometric perspective, understanding firm-level motivations for international patenting is crucial for gaining insights into the dynamics of innovation and intellectual property protection in the global economy. Empirical studies have shown that firms engage in international patenting for various reasons, including market access, technology transfer, and strategic considerations (Hu & Jefferson, 2009). Firms protect their exported products from imitation and piracy by patenting internationally (Grupp & Schmoch, 1999). Other firms intend to maximise their global intellectual property protection and gain a competitive advantage over the local firms (Hsu et al., 2015). Such global operations provide access to cross-border knowledge (Lai et al., 2017) leading to collaborative innovation (Arora et al., 2016). Firms with greater capacity to finance and manage complex patent portfolios (Li & Wu, 2015) also patent in other countries. In addition, the decision to file for patents abroad may depend on a range of factors such as firm size, R&D intensity, industry structure, and country-specific institutional and legal environments (Huang & Jacob, 2014). Finally, innovation quality plays an important role, as firms that generate higher-quality innovations are more likely to patent abroad to protect and monetise their inventions (Beneito et al., 2018).

Macro Perspective of International Patenting: Understanding Country Level Contributing Factors and Ensuing Impact

The macro perspective of international patenting focuses on the contributing factors at the country level and the impact of such patents on the economic growth and development. One of the primary determinants of foreign patenting is a country's level of economic development (Khan & Sokoloff, 2001). According to Park (1999), a strong intellectual property rights (IPRs) regime has a positive and substantial impact on international patenting. Because countries with stronger IPRs protection are more likely to attract foreign investment in innovation (Blind & Jungmittag, 2004). Research has shown that countries that are parties to international patent agreements tend to have higher rates of foreign patenting (Maskus, 2000). Eaton and Kortum (1996) pointed out that due to territorial nature of the IPRs and extensive costs of international patenting the decision of where to patent affords information regarding where the innovators' ideas are being used. The results suggest that foreign patenting is larger with smaller distance between two countries, larger ability of the destination to absorb technology (as measured by the level of human capital), and higher relative productivity of destination. The variations in the levels of outward-bound international patenting between countries is attributed to trade-related influences namely exports and outward foreign direct investment (Yang & Kuo 2008).

Implications of Non-Resident Patents on Host Country

Foreign patents have important implications for the host country's technological and economic progress. On the one hand, foreign patents can facilitate the diffusion of the new technologies and knowledge spillovers from information in the patent applications, leading to innovation and productivity gains for the host country (Park, 1999). Eaton and Kortum (1996; 1999) concluded that productivity growth in other countries is driven mainly by the innovation activities of leading research economies such as the US, Japan and Germany. Bottazi and Peri (2003) takes a different perspective and find that developing countries with low level of human capital that are located far from knowledge centres could hardly gain from non-resident patents unless their technology bases were significantly improved. In contrast, Xu and Chiang (2005) confirmed that both developing countries and technology laggard countries enjoyed technology spillover from the non-resident patents filed by leading industrial countries. The other set of studies highlights the consequences of technology diffusion by international patenting using non-resident patent data (Archontakis & Varsakelis, 2017). Kotabe (1992) states that foreign patents help to improve the technological strength and prosperity of domestic firms and, consequently, of a domestic economy.

In this dissertation, we argue that when a recipient country's absorptive capacity is high (low) as the technological gap from the source country is narrow (high), the imitation risk for the patentee in the source country is high (low). As a result, a firm from the source country has an incentive to patent in the destination country. The overall technological capabilities of a home country and technological gap (between patent recipient country and the country with highest technology index in a particular year) play an important role in driving non-resident patenting. Previous studies do not provide strong evidences for such drivers taking different country cases. Apart from the drivers, it is also important to examine how the rise in non-resident patenting affects the receiving country. For such countries, the impact of non-resident patenting may also vary with level of economic development. However, the current literature does not focus on the potential linkages through which non-resident patents contribute to the host country's development. Thus, we explore host country's investment in R&D, patenting by residents and TFP as potential channels through which non-resident patents contributes to the nation's economic growth. These channels have not been explored simultaneously in the current literature.

Data and Empirical Strategy

Methodology

For empirical purpose, we used gravity model framework to examine the bilateral flow of patent applications between source and destination countries. We applied panel data techniques (or negative binomial regression) to analyse the technological capabilities of home countries, and technological gap between home and host countries as key determinants of foreign patenting. The total numbers of country pairs (as we are examining bilateral flow of foreign patenting) are 14762. This study uses panel data analysis to quantify the effect of technology index (proxy of technological capabilities computed by authors) and technological gap (computed using technology index values) on foreign patents and in turn its influence on technology trade. First, we did estimations for a full sample (122 countries) and then estimate them by subgroups of high-income and middle-income countries, as based on the World Bank (2016) classification. These split samples helped us in measuring the varying effects of technological capabilities, technological gap and the index of patent rights on non-resident patenting by different income groups.

To examine the impact of non-resident patenting on innovation activity and productivity growth of the host country, we use Crepon et al. (1998) CDM (initials of three authors Crepon, Duguet, and Mairesse) model to revisit the innovation-productivity relationship based on cross-country data. Most scholarly investigations apply the basic CDM model for firm level studies. We extend this literature and propose a variant of the CDM model using country level innovation and productivity indicators. This model is a system of four non-linear equations (sample selection equation, innovation input equation, innovation output equation and productivity equation) with limited dependent and count data variables. It also deals with selectivity and simultaneity in this system using Heckman's two step selection model and reduced form of independent variables (lagged values of simultaneous variables) by disclosing the parameters of the preceding equations respectively. We use different estimation techniques for all four equations as per the requirement. Sample selection equation and innovation input (R&D) equations are estimated by using Heckman's two-step selection model (with fixed effects). Heckman models help to resolve the endogeneity resulting from sample selection, but do not account for independent variables that are endogenous for other reasons. For innovation output (patent) equation, we used negative binomial regression technique as our dependent variable is count data and it is overdisperrsed. We first include only key variables of interest and later include control variables. Productivity equation was estimated by using panel data techniques with fixed effects. We have performed time fixed effects and country fixed effects tests in all the specifications to check year specific and country specific effects.

Data

For the first objective of this thesis, our sample size is 122 countries including high and middle-income countries. These 122 countries have been selected on the basis of data availability. To evaluate the factors (technological capabilities of home countries and technology gap of host country) affecting non-resident patenting, we use macro indicators of each country for time period 2001 to 2019. We construct a technology index (TI) using both input and output indicators of innovation to analyse the technological capabilities of a country that contributes toward its patent-seeking and filing capacity across countries. For patent applications by non-residents, we use the WIPO statistics database (WIPO IP Statistics Data Centre). The patent count data were missing in case of many countries due to data reporting issue at WIPO either by filing office or origin country office. We have treated those data points as missing while applying regression because replacing the missing values by zero or minimum value one can deflate the real effect. The Index of Patent Rights is obtained from Prof. Walter G Park's website, gravity variables from CEPII (The Centre d'Études Prospectives et d'Informations Internationales) and information on European Patent Office (EPO) member states from EPO website. Rest of the indicators are collected from World Development Indicators database by World Bank.

For rest of the objectives, our sample size is 188 countries including high, upper middle, lower middle and lower income for the period 2001-2019. For patent application count data, we used WIPO statistics database (WIPO IP Statistics Data Centre). The total factor productivity data is obtained from Penn World Tables 9.0 and rest of the indicators are collected from World Development Indicators database by World Bank.

Key Findings

Our results provide strong evidence that technological capabilities encourage innovative activities within the country and patenting in the host country. Higher technological capabilities increase the likelihood that inventors become motivated to patent more in other countries that offer lucrative markets (refer Table 1 and 2). Also, with respect to the technological gap, we found that a higher technological gap discourages an innovative country from patenting in other countries. Hence, it appears that technological capabilities and technological gap can be the determining factors for patenting in foreign countries provided a minimum level of economic development carried by a country. We also examine the interaction between home countries' technology index and the host countries' patent rights protection. The coefficient of interaction is positively significant across all country groups. It indicates that keeping IPR constant, increase in TI will positively affect the non-resident patents inflow in the host country.

Table 1: Results of Foreign Patenting Equation

Dependent Variable ForeignPat	NB_FE All_to_All	NB_FE HI_to_All	NB_FE MI_to_All
TIHome	0.249***	0.345***	-0.311***
	(5.18)	(6.25)	(-3.47)
TechDistTIHost	-0.125***	-0.0538	-0.437***
	(-2.61)	(-0.98)	(-4.72)
Controls	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Pair fixed effect	Yes	Yes	Yes
Prob>chi2	0.0000	0.0000	0.0000
_cons	-1.668***	-1.862***	-5.359***
	(-13.06)	(-8.66)	(-17.88)
N	39469	28417	11052

Notes: t statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

Table 2: Results of Foreign Patenting Equation

Dependent Variable ForeignPat	NB_FE HI to MI	NB_FE MI to HI	NB_FE HI to HI	NB_FE MI to MI
TIHome	-0.203	-0.203	0.259***	-0.421***
	(-1.62)	(-1.62)	(3.33)	(-3.42)
TechDistTIHost	-0.216*	-0.216*	0.00486	-0.780***
	(-1.70)	(-1.70)	(0.06)	(-5.94)
Controls	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Pair fixed effect	Yes	Yes	Yes	Yes
Prob>chi2	0.0000	0.0000	0.0000	0.0000
_cons	-8.982***	-8.982***	-5.018***	-5.089***
	(-14.66)	(-14.66)	(-14.91)	(-11.16)
N	6046	6046	16180	5006

Notes: t statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

Our findings also suggest that foreign patenting positively impacts innovation and productivity in both developed and developing countries (refer Table 3). Using CDM model, our first equation used a Heckman's selection model and found that non-resident patents have a positive effect on R&D decision as well as on R&D expenditure. However varying effect on disaggregate level depends upon the existing level of technology. For example, in HI countries the coefficient of non-resident patenting is insignificant, it indicates that the existing level of technology is already high therefore the additional contribution is not significant.

Table 3: Results of R&D Outcome Equation

	HM_TS_All	HM_TS_HI	HM_TS_UM	HM_TS_LM	HM_TS_LI
RDexp					
PatAppNR	2.027**	0.0730	13.547***	-0.8505	-8972.28***
	(2.37)	(0.02)	(9.73)	(-0.09)	(-2.60)
IPR	0.180*	-0.549	0.0739	-0.1000	-0.0654
	(1.68)	(-0.45)	(1.55)	(-1.35)	(-0.66)
Controls	Yes	Yes	Yes	Yes	Yes
_cons	0.461	4.017	-0.357*	1.119**	0.0716
	(0.96)	(0.75)	(-1.86)	(2.30)	(0.26)
RDDummy			**Results of Selection Equation**		
SchoolEnrol	0.00640**	0.00126	-0.0107	0.00985	-0.0667**
	(2.52)	(0.20)	(-1.61)	(1.53)	(-2.22)
PatAppNR	39.681***	4.315	203.735***	106.393***	50781.79***
	(3.69)	(0.77)	(4.43)	(2.95)	(2.79)
IPR	0.694***	1.096***	0.841***	0.0922	0.971**
	(7.95)	(5.67)	(4.24)	(0.52)	(2.15)
Controls	Yes	Yes	Yes	Yes	Yes
_cons	-2.437***	-2.895***	-1.528**	-2.079***	1.103
	(-9.84)	(-3.19)	(-2.18)	(-4.53)	(0.89)
/mills					
Lambda	-0.759***	-4.157	-0.247***	-0.433*	-0.188
	(-3.13)	(-1.04)	(-2.94)	(-1.75)	(-1.32)
N	1157	587	297	219	54

Notes: t statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

In case of domestic patenting, the coefficient of non-resident patenting is positive and significant across all country groups except low-income countries (refer Table 4). It implies that non-resident patents are an important source of technology access for domestic firms and innovators. The local firms get the opportunity to study the underlying technology in those applications and invent new products or processes parallel to that technology avoiding the infringement. It further motivates domestic patenting activities. While in low-income countries due to low absorptive capacity domestic firms do not get such benefits.

Table 4: Results of Patent Equation

Dependent Variable	NB_FE_All	NB_FE_HI	NB_FE_UM	NB_FE_LM	NB_FE_LI
PatAppRes					
PatAppNR	2.44^{***}	2.64^{***}	13.59^{***}	44.801^{***}	16193.58
	(4.48)	(4.89)	(6.53)	(3.24)	(1.16)
L3RDexp	0.356^{***}	0.313^{***}	0.674^{***}	0.430	-1.188
	(12.19)	(10.64)	(3.78)	(1.41)	(-0.86)
IPR	0.478^{***}	0.357^{***}	0.158^{**}	0.0935	1.321
	(9.99)	(5.18)	(2.32)	(0.80)	(1.38)
Controls	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Pair fixed effect	Yes	Yes	Yes	Yes	Yes
Prob>chi2	0.0000	0.0000	0.0000	0.0000	0.0000
_cons	-0.0531	0.773^{***}	0.194	0.887^{**}	-1.495
	(-0.29)	(2.67)	(0.67)	(2.44)	(-0.69)
N	876	510	211	125	30

Notes: *t* statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

Finally, in the TFP equation we find that non-resident patenting has a positive and significant impact on TFP for full sample while varying effect on country sub groups (refer Table 5). It is due to other characteristics of the countries such as existing technology level, absorptive capacity, patent rights policy, FDI policies etc. Here, the results support the argument by Griliches (1980) and Crepon et al. (1998) that the innovation input (R&D) contributes to innovation output (resident patents), not to the productivity of the firm or country. Thus, it is innovation output that influence the productivity of the country. Our results indicate the same. In productivity equation results, coefficient of R&D is not significant though we have used R&D lagged variable assuming that the effect of R&D investment will be reflected on TFP after few years. Using lagged variable also deals with the problem of simultaneity in the CDM model.

Table 5: Results of TFP Equation

TFP	OLS_FE_All	OLS_FE_HI	OLS_FE_UM	OLS_FE_LM	OLS_FE_LI
PatAppNR	0.517**	-0.08	3.89***	6.42**	1593.122
	(2.04)	(-0.19)	(3.98)	(2.31)	(0.30)
L3RDexp	0.0113	0.000480	0.0249	-0.0248	0.283
	(1.32)	(0.05)	(0.88)	(-0.54)	(1.11)
L1PatAppRes	9.61e-08***	0.000000322	-0.000000100*	0.00000296*	0.000540
	(2.95)	(1.27)	(-1.84)	(1.67)	(0.14)
IPR	0.0219***	0.0393***	0.00165	0.0118	0.546**
	(2.77)	(2.79)	(0.15)	(0.60)	(2.58)
Controls	Yes	Yes	Yes	Yes	Yes
_cons	0.837***	0.713***	0.987***	0.990***	-0.0194
	(24.63)	(11.18)	(22.52)	(12.44)	(-0.05)
N	825	498	211	101	15

Notes: t statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

Conclusion

In this doctoral dissertation, we have approached the issue of international patenting from both host and home country's (bilateral) perspective and find variations in factors determining cross-country patenting. Further, as all economies in our sample have implemented patent policy changes to comply with TRIPs, our study offers empirical evidence about the impact of agreement on patenting. This study makes important contributions to the literature on innovation and economic growth at a country level. Although, most studies discussed innovation focusing on firm-level or industry-level innovation, our study analyses country-level innovation. In addition, it incorporates a comprehensive and large data set of HI and MI countries that allows for bilateral panel data analyses. Past studies at country level either focused on OECD or highly industrialised economies.

The findings suggest that promoting international knowledge flows and protecting intellectual property rights can stimulate R&D expenditure, innovation activities and productivity. Policymakers should consider different policy interventions to promote innovation in different income groups, and the drivers of TFP can differ based on the level of development of a country.

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ABBREVIATIONS

ALS	Asymptotic Method of Least Squares
BRICS	Brazil, Russia, India, China and South Africa
CDM	Crepon, Duguet, and Mairesse
CEPII	Centre d’Études Prospectives et d’Informations Internationales
CNIPA	China National Intellectual Property Administration
EPO	European Patent Office
FDI	Foreign Direct Investment
FE	Fixed Effects
GCI	Global Competitiveness Index
GDP	Gross Domestic Product
GNP	Gross National Product
HI	High Income
HM	Heckman Model
ICT	Information and Communication Technology
IIP	Institute of Intellectual Property
IMF	International Monetary Fund
IP	Intellectual Property
IPR	Index of Patent Rights
IPRs	Intellectual Property Rights
JPO	Japan Patent Office
KIPO	Korean Intellectual Property Office
LMI	Lower Middle Income
LI	Low Income
MLE	Maximum Likelihood Method
MNCs	Multi-National Corporations
NB	Negative Binomial
NBER	National Bureau of Economic Research
NISs	National Innovation Systems
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square

PCA	Principal Component Analysis
PCT	Patent Corporation Treaty
PROMETHEE	Preference Ranking Organisation Method for Enrichment Evaluations
PWT	Penn World Tables
R&D	Research and Development
SIPO	State Intellectual Property Office China
TAI	Technology Achievement Index
TCs	Technological Capabilities
TFP	Total Factor Productivity
TI	Technology Index
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UK	United Kingdom
UMI	Upper Middle Income
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
US	United States
USPTO	United States Patent and Trademark Office
WEF	World Economic Forum
WIPO	World Intellectual Property Organization
WTO	World Trade Organisation

Chapter 1

Introduction

1.1 The Context

This thesis is an endeavour to examine the determinants of non-resident patenting [1] and its impact on innovative and productivity performances of the host country. Past research suggests that innovation has been a key driver of countries' economic growth and development, and a prime factor of competition in the global market (Aghion & Howitt, 1992; Oslo Manual [2] OECD, 2005). A country's economic growth evolves through three stages in terms of technological change and productivity. First, factor-driven growth in which economies produce goods based on naturally available resources with low labour cost. Second, investment-driven growth in which economies accumulate technological, physical and human capital and offer investment incentives. Last, innovation-driven growth in which economies emphasise research and development (R&D), entrepreneurship, and innovation (Koh & Wong, 2005; Rostow, 1959; WEF, 2012; Raghupathi & Raghupathi, 2019). Schumpeter (1942) stated that R&D has a high effect on innovation that leads to productivity enhancement and economic growth. The endogenous growth models by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) indicate that innovations and the accumulation of knowledge are the drivers of total factor productivity (TFP) and economic growth. The empirical studies on the impact of innovation on countries productivity are sizeable; however, the evidence emanating specifically from non-resident patenting are

[1] The terms non-resident patenting, cross country patenting, foreign patenting and international patenting has been used interchangeably in this thesis.
[2] The Oslo Manual is an international resource that provides a common framework for measuring innovation in a more inclusive manner across the economy. It offers guidelines for collecting and interpreting data on innovation. It seeks to facilitate international comparability and provides a platform for research and experimentation on innovation measurement. Many countries and international organisations recognise the importance of innovation measurement and have developed capabilities to collect such data. It is jointly published by the OECD and Eurostat.

limited, rather mixed and devoid of clarity. Moreover, the empirical research is mostly focused on the impact of R&D and foreign direct investment (FDI) on productivity with a few studies analysing export related spillovers. Therefore, this thesis besides examining drivers of non-resident patenting, its productivity effect, predominantly aims to explore the impact of non-resident patenting on the innovation activities of host country and provide empirical evidence on it including for emerging economies. With empirical findings based on rich country-level data, this research is expected to contribute by deepening understanding of the conditions under which the innovation and productivity of host countries with different economic structures benefit from non-resident patenting.

R&D effort considered as an important input to the innovation economy. Arrow (1972) suggested that knowledge is a public good that can be created by an optimal level of investment in innovation process in a competitive market. Therefore, intellectual property rights are required to appropriating the benefits of the investments made in innovation. Further, several studies examine the importance of patents[3] for incentivizing innovation, international technology diffusion, knowledge spillovers and analyse its other aspects such as international patenting. Maskus (2004) stated that the information contained in the patent applications filed by foreign applicants is a major source of technology diffusion to local firms. The local firms get the opportunity to study the underlying technology in those applications and invent new products or processes parallel to that technology avoiding the infringement (Sharma & Saxena, 2012). Thus, non-resident patenting influences domestic R&D investment to an extent.

Further, Rivera-Batiz and Romer (1991) and Coe and Helpman (1995) provide the evidence that a country's TFP growth depends upon both domestic R&D effort and on foreign R&D spillovers through imports. Keller (2002) states that 20% of an economy's productivity growth

[3] Patents are among the seven intellectual property rights and are also the focus of this research.

depends upon imports and foreign technology transfers. Coe and Helpman (1995), Crespo et al. (2002) and Griffith et al. (2000) argued that foreign sources of technology have been an important source of productivity growth for developed economies. While Savvides and Zachriadis (2005) stated that developing economies invest less in domestic R&D, therefore technology diffusion across international borders for these economies plays a crucial role for TFP growth.

The influence of foreign technology on TFP growth depends upon country's ability to adopt and implement new technologies. In the context of technology diffusion literature, the Global Competitiveness Index (GCI) is an important indicator to assess the country's ability to adopt and implement new technologies. GCI is a measure of national competitiveness developed by the World Economic Forum (WEF). It is calculated based on a variety of factors including institutions, infrastructure, macroeconomic stability, health and primary education, higher education and training, goods market efficiency, labor market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation. The index is widely used by policymakers, academics, and business leaders to assess the competitiveness of different countries. It includes indicators such as the availability of the latest technologies, the quality of scientific research institutions, the extent of business R&D activity, and the number of patents filed. Existing studies shows a strong positive correlation between a country's technological readiness and its economic growth (Alcalá & Ciccone, 2004; Chen & Chang, 2012). A study by Cristina and Cantemir (2012) claims that the GCI is a significant predictor of FDI inflows. It also suggests that countries with higher levels of technological readiness are more attractive to foreign investors. Chen and Dahlman (2005) find that countries with higher GCI value tend to have more developed technological infrastructure and greater level of technology diffusion. Similarly, Dutta et al. (2016) observes that GCI ranking of a country is positively correlated with its level of technology adoption and innovation. Further, Hausmann et al.

(2011) show that a country's technological capabilities are the key driver of competitiveness. Though country's technological capabilities are closely related to technology diffusion. It means that countries with higher levels of technological capabilities are more competitive and tend to have higher levels of economic growth

The existing literature provide evidence that foreign influence is an important factor to stimulate country's productivity growth. In this thesis, we attempt to estimate two important aspects of international patenting (1) the factors influencing underlying international patenting in different countries (2) its impact on host country's innovativeness and productivity growth using country level innovation indicators by a different approach.

The introduction chapter is organised as follows: Section 1.2 comprises definitional framework of the thesis. Section 1.3 throws some light on patent cooperation treaty, its genesis, objectives, and impact. Section 1.4 gives insights of Park Index value to capture changes in IP laws. Section 1.5 emphasises on the scope of the study. Section 1.6 provides an overview of international patenting. Section 1.7 highlights the research gaps and objectives of the thesis. Section 1.8 outlines patenting as a measure of innovation. Section 1.9 explains the data sources and methodologies. Section 1.10 presents the organization of the thesis.

1.2 Definitional Framework

This section provides the definitional framework for this thesis. It explains the key technical terms used in this thesis referring literature. First, it defines innovation then it explains non-resident patenting and its types in terms of origin and destination country. Further, it offers a detailed description of the input indicator i.e., research and development (R&D) and output indicator i.e., patent application, of innovation to delineate the scope of this study. Lastly, it gives the definition of total factor productivity.

To define ‘innovation’ this study referred to Oslo Manual (2018). The general definition of innovation as per the Oslo Manual is as follows:

Innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

1.2.1 Non-Resident Patenting

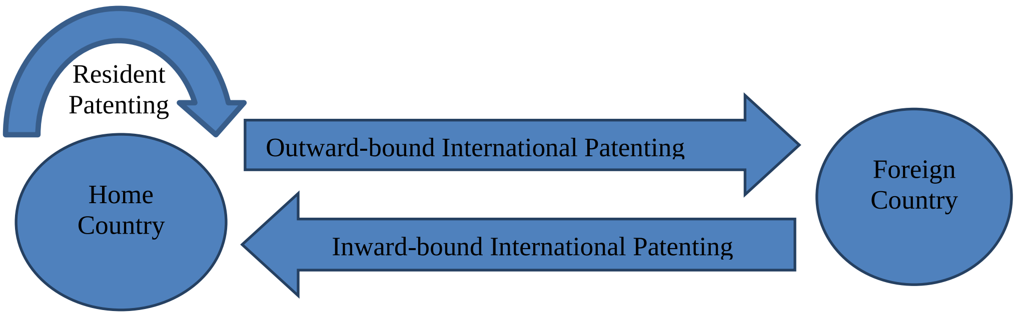
Non-resident patenting refers to the process of seeking patent protection for an invention in a foreign country. This is often done by individuals, companies, or organizations who wish to protect their intellectual property in other countries. Foreign patenting can be a complex and costly process, but it can provide significant benefits for inventors and companies.

According to WIPO non-resident patenting means a patent application filed with a patent office of a given country/jurisdiction by an applicant residing in another country/jurisdiction. For example, a patent application filed with the USPTO by an applicant residing in France is considered a non-resident patent application for the USPTO. Non-resident patent applications are sometimes also referred to as foreign patent applications. In other words, non-resident patent is a filing patent, in which the nationality of the assignee is different from the nationality of the examining and granting office, thus it represents domestic patents owned by foreign investors (Caviggioli, 2011; Ma et al., 2021). Non-resident patenting refers to the procedure of filing a patent application in a foreign country, whereby the patent holder is granted exclusive legal rights within that country to prevent any unauthorised individual or entity from producing, using, selling, or distributing the patented invention without prior permission (Ma et al., 2021).

To understand the concept of non-resident patenting, it is important to have clarity about host and home country. Host country refers to the patent receiving country or destination country for patent application filed by the applicant from any other country. Whereas home country refers to an innovating country or source country of a patent application. In other words, it is the country of origin of a patent application. For example, a patent application for technology invented in the US filed by the applicant (US resident) to Japan patent office. Here the US is home country or patent origin country and Japan is a host or destination country for the patent application.

Willoughby and Mullina (2021) distinguish between domestic patenting and non-resident/international patenting in the internationally oriented patent literature. They classified international patenting into inward-bound international patenting and outward-bound international patenting. Domestic patenting occurs when inventors or their assignees apply for patents in the country where the invention took place (i.e., home country), whereas inward-bound international patenting occurs when inventors or their assignees from abroad apply for patents in that same "home" country. Outward-bound international patenting occurs when inventors or their assignees from the home country apply for patents for their inventions in foreign countries (or host countries). Outward-bound international patenting, of course, is inward-bound international patenting from the vantage point of the country that issues the patents, and inward-bound international patenting is outward-bound international patenting from the vantage point of the country from which the inventions originate (refer Figure 1.1).

Figure 1.1: Types of Patenting



1.2.2 R&D

Research and experimental development (R&D) refer to "creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications" (OECD, 2002). Griliches (1990) establishes that R&D is an input into the knowledge production function that leads to output in the form of patent.

1.2.3 Resident Patent

According to the Oslo manual (2005), "a resident patent is a legal property right to an invention, which is granted by national patent offices. A patent gives its owner sole rights (for a certain duration) to exploit the patented invention; at the same time, it discloses the details of the patent to allow broader social use of the discovery." The number of patents granted to a given firm or country may reflect its technological dynamism; an examination of the growth of patent classes can give some indication of the direction of technological change. Patent statistics are increasingly used in various ways as indicators of the innovation output.

1.3 The Patent Cooperation Treaty

An inventor must file a patent application in each country in which the invention is to be exploited. Until the advent of the patent cooperation treaty (PCT), a separate application complying with varying formality requirements has been necessary for each such country. International cooperation with respect to patents was begun with the Paris Convention of 1883, adhered to by the US and most of its trading partners. The Paris Convention does not have any provision for formality requirements such as language, or fees. It has two key provisions: (1) the national treatment principle - nationals of all member countries will be treated equally with nationals of the country receiving a patent application under the Convention (2) the one-year priority period - applications filed within one year after first filing in a member country will be treated as if filed in the other countries on the date of first filing. Many inventions are not in use when the first application is filed and completion of all these formalities may cost a big amount. Therefore, a decision to seek patent protection in foreign country postponed frequently until near the end of the priority period. This was the scenario before the adoption of PCT. The patent cooperation treaty is administered by WIPO, facilitates the filing of patent applications worldwide. The Treaty entered into force on 24 January 1978, initially with 18 contracting states. As of 2021, PCT membership consisted of 155 contracting states (refer WIPO website for more details). The primary objective of PCT was to reduce this wasteful duplication by setting certain minimum standards for formalities of applications. An international application complying with those minimum standards filed in any PCT member country was thereby an application in all countries designated by the applicant. PCT was a crucial step towards the goal of reducing the expense and complexity of international patenting. PCT applications have dominated direct applications in recent years and become the main application channel for international patenting.

1.4 The Park Index and Its Uses

The Park Index was developed by Professor Walter G. Park of American University. It is a tool that has been developed to measure changes in patent rights regime and its impact on innovation and economic growth. It uses data on IP (patentable inventions; membership in international treaties; duration of protection; enforcement mechanisms; and restrictions) to create a composite score that reflects the strength of a country's patent rights regime. It is constructed for 122 countries with the gap of every five years from 1960 to 2015. The Park Index has been used in several studies to analyse the impact of changes in intellectual property laws on innovation and economic growth. For example, Park and Ginarte (1997) found that countries with stronger patent laws tended to have higher levels of innovation particularly in industries such as pharmaceuticals and biotechnology. They used the Park Index to measure the impact of changes in patent laws on innovation in 60 countries for the period 1960-1990. World Intellectual Property Organization (WIPO) has used the Park Index for the policy analysis purpose. WIPO assess the IP systems of various countries using the Park Index and provide recommendations for improving those systems.

1.5 Scope of the Study

There is extant literature examining R&D, patents, innovation, and their impact on an economy. More recently the significant increase in international patent applications filed under WIPO's Patent Cooperation Treaty indicates the growing popularity of international patenting among the innovators. It has shifted the focus of innovation economy researchers towards observing an importance of international patenting, in addition to domestic patenting from innovation, international trade and economic policy (Schiffel & Kitti, 1978; Soete & Wyatt, 1983; Maskus, 2008; Romero-De-Pablos & Azagra-Caro, 2009; Frietsch & Schmoch, 2010; Keupp et al., 2012; Huang & Jacob, 2014; Geng & Saggi, 2015).

The pursuit of international patent protection is an outcome of internationally oriented R&D and innovation activities by large multinationals worldwide. International patent protection is a process by which domestic inventors' appropriate value globally from their locally grown technological innovations. Academic researchers are increasingly interested in the topic of international patenting and seek to understand the various dimensions of innovation and patenting by reviewing the available literature. However, this task is challenging due to the scattered and vague nature of the literature that covers a range of related but distinct topics. The literature covers various dimensions of innovation and patenting, such as the impact of intellectual property rights on innovation, variations in national IP rights, domestic intellectual property laws' influence on endogenous research, and innovation. Some literature also covers the intersection of international economics and law, including the effect of patent rights enforcement on FDI and the accessibility of foreign intellectual property settings. Additionally, some topics focus on the contentious place of intellectual property in international trade negotiations, and the role of patenting in international trade. Due to the fragmented nature of this literature, deriving convincing principles for intellectual property strategy can be challenging for managers and policymakers. (Willoughby, 2020).

In that context, various scholars have explored the factors associated with the rise in international patenting. Such as influence of national innovation systems, particularly in countries with a relatively high representation of foreign inventors, multinational corporations, and global R&D centers (Shapira et al., 2011); catalytic role of foreign direct investment (Zekos, 2014); role of international research-driven collaborations (Peeters & de la Potterie, 2006; Thomson & Webster, 2013; Thurner et al., 2015); emergence of new fields of technology (Pugatch et al., 2012) or new technology-intensive service activities (Maskus, 2008); relationship between increase in the stock of the knowledge in an economy and the subsequent strengthening of its IP rights, IP institutions and IP enforcement (Caliari & Chiarini, 2021; Maskus, 2000; Park, 2008). Several scholars noted the relative levels of patenting in comparison to the levels of innovativeness or high-technology intensity of countries (Basberg, 1983; 1987; Chang et al., 2015; Schiffel & Kitti, 1978; Schneider, 2005). Chadha (2009) concludes that technology proxied by foreign patents has a positive impact on exports. However, scholars from different subjects like economics, innovation, trade, public policy, and law have given an attention to this field of research. Existing literature do not reflect the economic and business correlates of patenting, drivers of patenting, or the relative impact of patenting on the different economies or on the performance of firms.

It provides a scope to contribute to this literature by investigating the relationship between the international patenting of inventions and economic development in the host countries. In other words, the relationship between the pursuit of foreign patent rights by inventors or their assignees and economic development in the countries in which the respective inventors apply for a patent is analysed. The main and distinctive purpose of the analysis presented in this thesis is to establish plausible evidence for the proposition that inward international patenting matters for economic development in the host countries and home countries from which innovations emerge.

1.6 International Patenting: An Overview

There is a plenty of literature available highlighting the importance of innovation and technological development for the economic growth and welfare (Baumol, 2002; Rosenberg & Nathan, 1982; Schumpeter, 1934; 1942; Solow, 1956; 1957). However, IP management studies have traditionally been limited to developed nations (Granstrand, 1999; Hanel, 2006). The transition in the patenting activities started somewhere in the mid-1990s when Trade-Related Aspects of Intellectual Property Rights (TRIPs) came into existence (Granstrand, 1999; Pisano, 2006; Pisano & Teece, 2007; Reitzig, 2004; Somaya, 2012).

On January 1st, 1995 the World Trade Organisation's (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) came into effect that necessitated the member countries to introduce TRIPs obligations into their national legislations and regulations. The agreement also had the provision of transitional periods for the developed, developing, and least developed countries till 1996, 2000, and 2006, respectively to make the required changes. Some developing countries were to introduce product patent protection in a particular area of technology e.g., pharmaceutical products and agricultural chemicals as per their commitments at WTO. Such countries had a special transitional rule of further five years up to 2005 to introduce protection in that area. The increased values of the index of patent rights constructed by Park (2008) highlights the growing strength of patent protection across the member states (refer Table 1.1).[4]

Table 1.1: Park's Index of Patent Rights				
Countries	**2000**	**2005**	**2010**	**2015**
U.S.A.	4.88	4.88	4.88	4.88
Japan	4.67	4.67	4.67	4.67
Netherland	4.67	4.67	4.67	4.67
France	4.67	4.67	4.67	4.54
Germany	4.67	4.67	4.67	4.67
U.K.	4.54	4.54	4.54	4.54
China	3.09	3.96	4.08	4.42
India	2.27	3.76	3.76	3.76
Malaysia	3.03	3.48	3.68	3.23
Mexico	3.22	3.42	3.75	3.75
S. Africa	3.63	3.75	3.88	3.88
Australia	4.33	4.33	4.33	5.00
Source: Ginarte and Park (1997), Park (2008) and Prof. Walter G Park’s website (index values available till 2015)				

As most of the developing countries complied with TRIPs agreement, the cross-country patenting increasing considerably. The global patenting activity has seen an upward trend since 2004, except in 2009, where the patent application declined 3.8 percent due to the financial crisis. Along with developed countries, developing countries has also seen an upsurge in the overall patenting activity. Furthermore, developing countries have become major partners in such technology trade (both as source and recipient country). The rise of China as the second largest PCT applicant country in the year 2016 is a case in point (WIPO, 2017). However, such economies remain underrepresented in the literature that focuses on cross-country patenting.

Eaton and Kortum (1996) argued that innovators’ decision of where to patent affords further information regarding the spatial applicability of their ideas, since intellectual property rights (IPRs) are national in scope and patent applications involve extensive costs. Eaton and Kortum (1996) used a cross-section of 19 OECD countries to suggest that cross-country patenting is larger with smaller gap between two

[4] Park’s Index of PRs shows increased values in 2005 for developing countries such as China, India, Malaysia, Mexico, South Africa etc.

countries, larger ability of the destination to absorb technology (as measured by the level of human capital), and higher relative productivity of destination. Over 50% of the productivity growth of these 19 OECD countries depended upon just three countries namely U.S., Germany, and Japan. Park (1999) has shown that IPRs regime of the receiving country has a positive and significant impact on the international patenting. Bosworth (1984) shows that the foreign patent which flows to and from the UK have a strong association with foreign direct investment. Dosi et al. (1990), based on patent flows among OECD countries establishes that cross-country patenting is positively associated with trade flows. As mentioned earlier, most such works are based on the developed economies including OECD nations.

1.7 Research Gap and Objectives

There is vast literature available examining the importance of foreign patenting in different aspects with much of it focused on developed countries. More recently, the attention of scholars has shifted to studying the importance of foreign patenting in emerging economies. Earlier Raghupathi and Raghupathi (2017) analyses the role of economic indicators in country-level innovation, represented by patents in the technology sector. Innovation indicators include the ratio of patents owned by foreign residents and the number of patent applications in each industry in the technology sector. Economic indicators include GDP, gross national income, labour cost, R&D expenditure, real minimum wage, tax revenue, and education enrolment. This study was conducted for the period of 2000 to 2010 and focused on OECD countries. The results indicates that the countries with low GDP rely on foreign collaboration for innovation; education enrolment stimulates innovation; among the sectors, government and higher education have higher R&D expenditures than private and non-profit sectors. The study period is dated and it did not differentiate and reflect the findings for countries with different economic structure. Willoughby (2020) examine the relationship between the pursuit of foreign patent rights by inventors or their assignees and economic development in the countries in which the respective inventors reside. This empirical analysis establishes plausible evidence that outward-bound international patenting matters for economic development. The research about patenting profiles of 78 countries over 14 years concluded that countries whose residents exhibit a relatively high proclivity for obtaining foreign patent protection for endogenous inventions are likely to enjoy relatively high levels of wealth per person.

Most of the literature on innovation and patenting is concerned primarily with domestic patenting, and most of the literature on international patenting focus either on developed countries or based on firm-level patent data. However, the desire of inventors or innovators seeking multinational IP protection for their inventions is both significant and prominent.

The emergent research on this topic has revealed that the exploitation of foreign countries' patent systems by innovators for the commercialization of technology invented in their home country is an important factor for innovation and national economic development (Willoughby & Mullina, 2021). The question that remains unanswered, however, is whether the determinants of international patenting vary from country to country, and the host country gets a different impact of inward international patenting based on their economic structures.

This thesis argues that outward patenting by a country must be linked to the overall technological capabilities (TCs) of a country. TCs are generally defined as the capacity of a given country to generate, use, adapt, absorb, and transmit knowledge to develop and master, in an effective way, technological innovations directed to promoting growth (Kim, 1980). Lall (1992) proposes a classification of three key components within the concept of Technological Capabilities: physical capital, human capital, and technological effort. Physical capital represents a fundamental capability, as no industry can effectively operate without a certain level of essential infrastructure such as machinery, transportation networks (like railroads and highways), and more. Human capital, on the other hand, is nurtured through higher education, training, and experiential learning. It enhances the capacity to more efficiently leverage the potential embedded in physical assets, as articulated by Lucas (1988). However, the presence of human capital alone is insufficient. In this perspective, technological effort assumes the role of a higher-level competence. It functions as a *meta-competence*, that is, a competence in further developing and exploiting other competencies thereby ensuring a more comprehensive and effective utilization of resources and capabilities.

Further, there is a need to understand the role of technological gap in international patenting. We argue that when a recipient country's absorptive capacity[5] is high (low) as the technological gap from the source country is narrow (high), the imitation risk for the patentee in the source country is high (low). As a result, a firm from the source country has an incentive to patent in the destination country (Eaton & Kortum 1996). Particularly, from a developing recipient country's perspective, the knowledge diffusion from foreign patenting is of utmost importance that further contributes to their technological development and concomitantly economic growth.

The initial gap theory by Gerschenkron (1962) argues that developing nations possess a unique advantage through their state of relative backwardness, which affords them the opportunity to access and adopt technologies and best practices that have already been developed by more advanced countries. The gap provides the economic incentive to catch up, while the political process drives institutional innovation. However, later theoretical studies explained that technological laggard countries may face a disadvantage of backwardness because of their limited absorptive capacity, and thus the existing technology gap may impede learning in the international technology diffusion (Aghion et al., 2005; Castellacci, 2011; Popp, 2006). It is worthwhile to explore

[5] A specific subsection is given in this chapter that elaborates the terms technological capabilities and technological gap along with their operationalization.

the impact of technology gaps on developed and developing countries separately.

The national innovation systems (NISs)[6] of developing countries are predominated by lack of institutional capacity, and there is a significant distance between developed and developing countries' situation in terms of their NISs (Arocena & Sutz, 2000). In the doctrines of evolutionary economics, such NISs emerge as an important policy tool to know national institutions and capabilities, which account for competitiveness (Lema et al., 2018). As not only most developed economies are involved in cross-patenting but developing economies are also major partners (both as source and recipients) in the trade of ideas. Thus, the overall technological capabilities of a home country and technological gap between patent origin and patent recipient countries plays an important role in driving non-resident patenting. Previous studies do not provide strong evidence for such drivers taking different country cases. Apart from drivers, it is also important to examine how the rise in non-resident patenting affects the receiving country. The impact of non-resident patenting may also vary on developed and developing economies in terms of innovation and productivity.

Past studies shows that the benefits from foreign R&D investment can be transmitted through different channels such as FDI, trade, cross-country patents etc. and affect domestic R&D investment decision. However, the relation between foreign technology inflows and domestic R&D investment is ultimately an empirical question. Results of the existing literature are inconclusive, and evidence varies from case to case.

There are other reasons whereby non-resident patenting affects resident patenting of a host country directly: (a) expansion of R&D activities by MNCs in host countries lead to increase in competence levels.

[6] National innovation systems define as "the network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987; Page. 1).

Therefore, host country researchers become involved in more advanced R&D projects, some of which will eventually result in patents. These patents will often be filed by a team of researchers, some of whom are residents of host countries while others work for the MNC in the home base or in other industrialised countries. Gerybadze and Merk (2014) identified structural changes and the extent of generation of new knowledge by studying the development of host-country patenting with contributions of local inventors. (b) Patent applications filed by foreign applicants is a major source of technology diffusion to local firms (Maskus, 2004). The local firms get the opportunity to study the underlying technology in those applications and invent new products or processes parallel to that technology avoiding the infringement (Sharma & Saxena, 2012). The local inventors may file patents for such inventions.

Further, not all type of innovations in developing countries may be captured by R&D expenditure and by the patenting because they may be doing some incremental changes in their processes and all. So, if that is the case, we are including the foreign patenting in productivity equation separately.

The previous studies and findings on this subject have investigated mainly the policy implementation in developed countries. In context of developing countries, there is a lack of empirical evidence about determining factors of international patenting and its impact on host economy. This thesis captures the factors behind the rise in international patenting after policy changes took place in the year 2005 and its impact specifically in developing countries.

Based on the above discussion, the objectives of the study are as follows:

1 To investigate the technological capabilities of patent source country and technology gap of patent destination country from the country with highest technology index, that induce the cross-country patenting activity.

2 To explore the influence of non-resident patents on R&D investment of the host countries.
3 To examine the impact of international patents on the resident patents of the host country.
4 To study non-resident patenting as an important driver of Total Factor Productivity of the host country.

1.8 Patenting as a Measure of Innovation

Innovation refers to the introduction of novel goods, upgraded methods of production, new markets, better sources of raw materials and improved organization techniques (Schumpeter, 1942). Innovations can be classified into four categories namely product, process, marketing and organizational innovation. The Oslo Manual [7] concentrates on the first two Schumpter's categories, which it claims are relatively easier to define and measure. The first two comes under technological innovations and others are non-technological in nature. Product innovation refers to generation, introduction and diffusion of new products where the process remains unchanged. Process innovation is defined as generation, introduction and diffusion of new production process for the same product. Marketing innovations comprises new methods of capturing market like change in product design, packaging, promotional strategies, and different pricing methods. Organizational innovation means introduction of new managerial practices that help firms to reduce transaction costs, supplier costs and improve labour productivity.

Innovation as a concept posits challenges in terms of measurement. For instance, interviewing experts to identify major innovations in their respective fields and count them. However, it is subjective and difficult to provide an overall picture of innovation in a continuous manner (Nagaoka et al., 2010). R&D expenditure is often used as a proxy for innovation or technological progress (Schumpeter, 1942; Pakes & Griliches, 1984; Rivera-Batiz & Romer, 1991: Coe & Helpman, 1995).

[7] The Oslo Manual definition of innovation is given in previous section.

However, expenditure is an input for R&D rather than an output of R&D, which should be innovation. Another candidate is total factor productivity or TFP but again, TFP is affected by factors other than innovation, and it has its own measurement problems, such as its procyclicality and difficulty in obtaining a good price index, particularly for goods with fast quality change or services.

Recently, patent information is increasingly used by scholars to analyse innovation and the innovation process. Because patent documents have been the only source of rich information on new technology, which is screened in a systematic manner by using a considerable amount of resources by governments over a long period of time. Patent data have commonly been used to analyse the innovativeness of the firm/country due to the following reasons: (1) Patent data is systematically compiled, has detailed information, and are available continuously across time (2) Patent documents help us to capture the geographic location, the time, and the technology of an invention (Sharma & Sharma, 2022).

The other reasons for the increasing use of patent data in recent years are twofold. First, systematic patent databases such as National Bureau of Economic Research (NBER), OECD patent database, European Patent Office (EPO), and Institute of Intellectual Property (IIP) in Japan for the analysis of innovation has been developed. Patent and related information generated by patent offices is also useful for companies to monitor the technological developments and patenting activities of rival firms. But without the development of such structured databases, it was almost impossible to use patent data for statistical analysis. Second, the high-quality computers and software became widely available. One can download the data from freely available databases from anywhere and conduct sophisticated statistical analysis with the help of software. It encouraged the large number of economists, management scholars, and policy makers in innovation economics and technological change to study this subject.

Thus, the research papers based on patent statistics, have been growing at a faster rate than patents themselves. However, existing literature also advised that patenting data should be used carefully and wisely as they are not completely problems free or correspond perfectly to innovation. Patent data is affected by the idiosyncratic features of a particular patent system of a nation at a given point in time. It might not be easy to match other economic data. However, if used carefully and wisely, it will lead us to new insights into innovation. The empirical studies on the use of patents are limited and overall are not fully conclusive (Guellec & van Pottelsberghe de la Potterie, 2007; Lopez, 2009). The companies usually keep their strategic choices confidential and protected. Thus, it is not easy to determine whether an invention would have been developed without patent protection. Previous studies concluded that the effectiveness of patents as a mechanism for appropriating the return from R&D varies across firms and industries. Secondly, patents are more effective for product innovations than process innovations. Lastly, patents are more often used for radical innovations than incremental inventions (Levin et al., 1987; Cohen et al., 2000; Mansfield et al., 1981; Mansfield, 1986).

Existing literature also claims that firms practice different mechanisms to appropriate returns from their innovation. First, rely on trade secrets, especially when technology is progressing so rapidly that it may be outdated before a patent issues. Second, firms use complementary assets (e.g., resources and capabilities which are not linked to innovative activities directly but are crucial for taking out profits from innovation like manufacturing and marketing). The relative importance of such mechanisms contributes to define the role of patents in each industry.

Patenting is a key strategy in pharmaceutical, chemical and petroleum industries, while it seems to be less important in primary metals, electrical equipment, metals, and textile industries (Mansfield, 1986). He found that in Pharmaceuticals, 65% of inventions would have not been developed without patents, in Chemicals it is 30%, while in all the other sectors the percentage is always lower than 20%. Hence differences across industries (or sectors) are strikingly large.

Patents may provide only imperfect protection to innovators. Often, patents may be avoided or may provide little protection because of stringent legal requirements. Furthermore, alternative means of appropriations, like lead time, secrecy, and service efforts (reputations, sales) can be more effective mechanisms for appropriating the returns from innovation.

Past literature shows that patent data has been used widely as an innovation indicator to identify the technical expertise of a country or firm. We examine the country's innovation activity using patent data in different ways as dependent variables determined by different country specific variables and independent variable that may affect the R&D investment, domestic patenting, and productivity of the host country. We used the number of patent applications filed at the different patent offices originated in other countries.

1.9 Data and Empirical Strategy

1.9.1 Data

The present thesis relies on country level data related to factors determining non-resident patenting and productivity growth of an economy. We conduct a methodological survey of the relevant studies that provides the information about the key determinants of non-resident patenting. Further, we explore the studies examined the impact of non-resident patenting on domestic R&D, patenting, and productivity. For this purpose, we explored around 50 articles published between 1962 to 2022 in scientific journals, and working papers from well-renowned universities, and institutions such as The World Bank, The International Monetary Fund (IMF) and the OECD. Based on this survey we constructed our variables with strong literature support.

To evaluate the factors affecting non-resident patenting and its impact on innovation activity that led to productivity growth of a host country, we use country-level data of each country for time 2001 to 2019. For first objective of this thesis, our sample size is 122 countries including countries from high- and medium-income groups. These 122 countries have been selected based on their patenting activity at US patent office from year 2001 to 2019 as USPTO is the highest non-resident patents receiving offices in the world. We have selected our country sample on the basis of a country filed patents (at least one patent in each year) at USPTO in minimum five years of the total time (2001 to 2019) of the study. For patent application count data, we used WIPO statistics database, WIPO IP Statistics Data Centre. Other indicators are collected from World Development Indicators database by World Bank, Prof. Walter G Park's website, CEPII (The Centre d'Études Prospectives et d'Informations Internationales) and European Patent Office website.

For rest of the objectives, our sample size is 188 countries including high-medium-low income for the period 2001-2019. These 188 countries are selected as per the availability of the data (dependent variables' data). For patent application count data, we used WIPO statistics database, WIPO IP Statistics Data Centre. Rest of the indicators are collected from World Development Indicators database by World Bank. To calculate the total factor productivity, we used data from Penn World Tables 9.0.

1.9.2 Methodology

The objective of this dissertation is to evaluate the factors affecting non-resident patenting and its impact on innovation activity that led to productivity growth of a host country. For empirical purpose, we used panel data techniques (or negative binomial regression) to analyse the relationship among technological capabilities, technological gap, and cross-country patenting. This study uses panel data analysis to quantify the effect of technology index and technological gap on foreign patenting and in turn its influence on technology trade. The total numbers of country pairs (as we are examining bilateral flow of foreign patenting) are 14762, as there are 122 countries for the period of 2001 to 2019. The patent count data (patent applications by non-residents) collected from WIPO statistics database were missing in case of many countries due to data reporting issue at WIPO either by filing office or origin country office. We have treated those data points as missing while applying regression because replacing the missing values by zero or minimum value one can deflate the real effect. First, we did estimations for a full sample (122 countries) of our countries and then estimate them by subgroups of high-income and middle-income countries, as based on the World Bank (2016) classification of economies. These split samples helped us measuring the varying effects of technological capabilities, technological gap, and the index of patent rights on non-resident patenting by different income groups.

To examine the effect of non-resident patenting on innovation activity and productivity growth of host country, we use Crepon et al. (1998) approach of CDM (initials of three authors Crepon, Duguet, and Mairesse) model to revisit the innovation-productivity relationship based on macro level data. Literature shows that the basic CDM model application is exclusively for firm level studies. We use a variant of the CDM model using country level innovation and productivity indicators for this study. This model is a system of four non-linear equations (sample selection equation, innovation input equation, innovation output equation and productivity equation) with limited dependent and count data variables. It also deals with selectivity and simultaneity in this system using Heckman's two step selection model and reduced form of independent variables by disclosing the parameters of the preceding equations respectively. The authors of CDM model used a comprehensive approach to the econometric analysis of their model, which is able to take into account the sampling error and simultaneity that can lead to the endogeneity of certain variables (e.g., R&D investment and innovation proxies such as patents), as well as the fact that the indicators may vary in their statistical nature (they may be continuous, integral, or ordinal). We used different estimation techniques for all four equations as per the requirement. Sample selection equation and innovation input (R&D) equations are estimated by using Heckman's two-step selection model (with fixed effects). When an omitted variable (i.e., an unmeasured variable not included in a model) creates a correlation between the error terms in these two stages, traditional techniques such as ordinary least squares (OLS) regression may report biased coefficient estimates. To resolve this potential bias, Heckman introduced the Heckman model (Gronau, 1974; Lewis, 1974; Heckman, 1976), a two-step process for data analysis. Also, Heckman models help to resolve the endogeneity resulting from sample selection, but do not account for independent variables that are endogenous for other reasons. We include one exclusion restriction variable in the selection equation to deal with the selectivity bias. An exclusion restriction variable must be correlated with the independent variables, but uncorrelated with the error term in the model. Our approach in selecting the exclusion restriction variable for R&D investment was based on the criterion that this variable should demonstrate a certain threshold of developmental progress. During the initial stages of variable selection, we conducted a thorough assessment of potential explanatory and exclusion restriction variables. We dedicated significant effort to conducting an exhaustive survey of literature and methodologies to guide our selection of these variables. Here school enrolment, secondary (% gross) is a suitable instrument variable because it influences the level of R&D in a country through its impact on the availability of skilled workers and researchers, as well as the level of technological development.

For innovation output (patent) equation, we used negative binomial regression technique as our dependent variable is count data and it is overdisperrsed. We first include only key variables of interest and later include control variables. We have performed time fixed effects and country fixed effects tests in all the specifications to check year specific and country specific effects. Productivity equation was estimated by using ordinary least square method with fixed effects. We calculated the total factor productivity growth by using growth accounting method.

1.10 Organisation of the Thesis

This thesis is presented in seven chapters. Chapter 2 provides detailed status of non-resident patenting worldwide. It also discusses the changes in the size of patenting with IP policy changes globally over the years. It discusses temporal trends of non-resident patenting along with separate cases of high and middle countries as source and destination of patent applications.

Chapter 3 presents an extensive review of the existing theoretical and empirical literature on different aspects of international patenting, innovation, and productivity. It also discusses the methodologies used and key findings of the previous studies to prepare the base for the present thesis.

Chapter 4 discusses the methodology, identification strategy and data used to examine the determinants of international patenting and its impact on host country. It highlights the evaluation issues in detail and explains how our identification strategy accounts for the issue of potential selection bias and endogeneity is addressed through our empirical approach. This chapter also elaborates the data sources and outlines the variables used in the study with literature support.

Chapter 5 discusses the results and findings of non-resident patenting equation. It provides the detailed analysis of the determinants of non-resident patenting in different country groups.

Chapter 6 provides the detailed analysis of the influence of non-resident patenting on host country’s innovation and productivity. It shows the results of CDM model estimations taking care of selectivity and simultaneity issues. Using CDM model on country level data is rare therefore it reflects the issues faced in the data and the given treatment to get the better estimation results.

Chapter 7 summarises the overall findings of the thesis followed by key observations, policy recommendations, limitations of the study and concluding remarks.

Chapter 2

Trends of International Patenting

2.0 Introduction

The previous chapter is about the overall introduction of the thesis. It also gives definitional framework where the key terms used in the research has been discussed in detail. It also includes motivation of the thesis, key objectives followed by brief discussion of data and methods used for the thesis. Lastly, it gives details on chapter wise organisation of the thesis. This chapter captures the trends of foreign patenting between 2001 to 2019. It displays the global patenting data and also discuss this data on disaggregate level. First it offers detailed section about top patent applicant countries in the US, Japan, Europe and BRICS. It provides the patent statistics in terms of patent filed and patent received. Patent filed means if the invention took place in country ‘A’ and patent application for the same is applied at the patent office of country ‘B’. Whereas patent received means total number of patent applications received by the patent office of country ‘A’ from any other country. It also gives details about the patenting activities (as applicant and recipient) of the countries based on income wise classification i.e., High Income (hereafter HI) and Middle Income (hereafter MI) countries.

2.1 Global Patenting

In the globalised world, patenting has increasingly become an international activity. Many firms are filing patents in foreign countries, and there is substantial literature available on this topic. This chapter captures the global patent application trends from 2001 to 2019. Applicants around the world filed 3.2 million patent applications in 2019. This represents a 3% decrease over 2018 due to a substantial decline in patent filings in China. It was the first decline since the 2009 financial crisis. Out of total 3.2 million applications, 2.2 million

(69.2% of the total) applications were filed by resident applicants, while non-resident applicant filed the remaining million (30.8%). The share of resident patenting decreased from 71.5% in 2018 to 69.2% in 2019, mainly due to the fall in resident filings in China (WIPO 2020).

Together, the top five offices State Intellectual Property Office (SIPO) in China, United States Patent and Trademark Office (USPTO), Japan Patent Office (JPO), Korean Intellectual Property Office (KIPO) and the European Patent Office (EPO) accounted for 84.7% of the world total of patent applications in 2019. The four BRIC countries – Brazil, China, India and the Russian Federation – rank among the top 10 offices except in some years Australia has been among the top 10 offices in place to Brazil (WIPO, 2020).

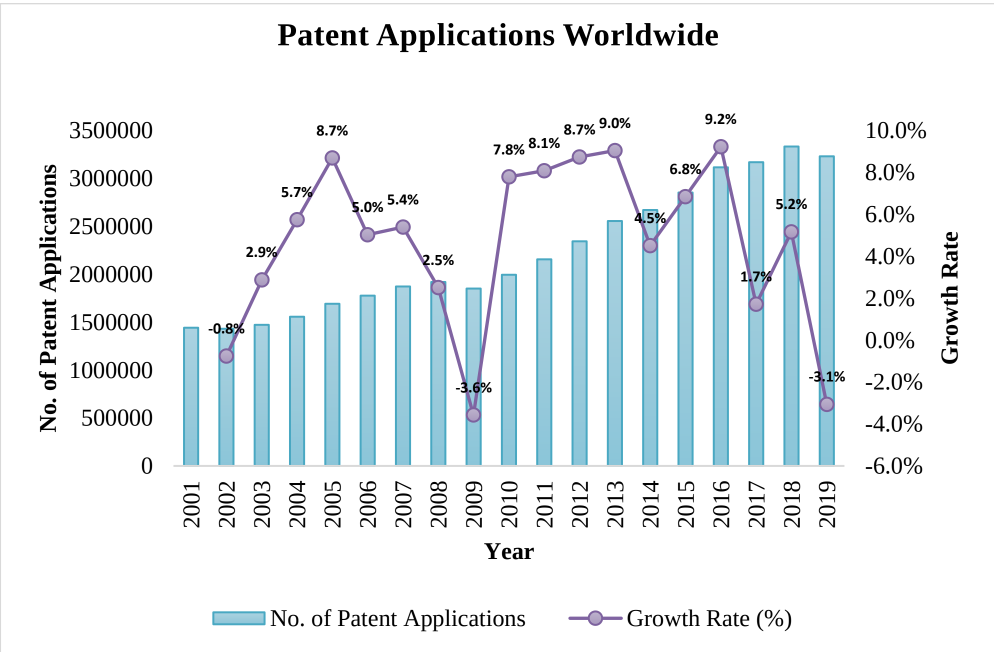
China started moving up from third position in 2009 and securing top position since 2011. Table 2.1 shows the patent applications received by the top 10 offices, broken down by resident and non-resident filings. The intellectual property (IP) offices of China (88.8%), Germany (69.2%), Japan (79.7%), the Republic of Korea (78.4%) and the Russian Federation (65.7%) received the bulk of their applications from resident applicants. In contrast, Australia (91.1%), Canada (88.4%) and India (63.7%) reported a large proportion of non-resident filings.

Table 2.1: Patent Applications Received by the Top 10 Offices (2019)

Country	Total	Resident	Non-resident
China	1400661	1243568	157093
US	621443	285113	336330
Japan	307969	245372	62597
Republic of Korea	218975	171603	47372
Germany	67434	46632	20802
Russian Federation	35511	23337	12174
India	53627	19454	34173
Canada	36470	16738	19732
France	15869	14103	1766
Australia	29758	13125	16633
Source: WIPO, March 2023			

The long-term trend shows patent applications growing worldwide every year since 2001. There are three phases of 2002, 2009, and 2019 during which patent applications have declined by 0.8%, 3.6% and 3.1%, respectively (refer Figure 2.1). The decline during 2002 is in alignment with the “Early 2000s Recession”. It was triggered by the “Dot-com Bubble” or “Internet Bubble” collapse in 2000. The dotcom bubble (internet bubble), describes the swift escalation in the value of US technology stocks, which was driven by investments in internet-based enterprises during the late 1990s. This term encompasses the period spanning from 1995 to 2000 when investors injected substantial amounts of capital into startups that operated via internet, anticipating that these nascent companies would generate profits in the near future. It affected the European Union, the US, Turkey, Argentina and other countries. This recession was relatively short and mild (Benoliel & Gishboliner, 2015). Dot-com Bubble led to actual declines in national and regional patents filed worldwide in 2002 and to a substantial decline in the growth in numbers of PCT applications. Due to the crisis, R&D expenditure growth declined as economic output fell from 4.6% yearly growth in 2000, to 2.2% in 2001 and 2.6% in 2002, before recovering to pre-crisis levels in 2004 (WIPO, 2010). Again in 2009, patent applications decreased by 3.6% due to the financial crisis. Most countries experienced a slowdown in the growth of patent applications in 2008 and an actual decrease in the numbers of patent applications filed in 2009. These tendencies apply to national and regional patent applications as well as PCT applications. However, like adjustments in R&D expenditure, the patent-filing response to the crisis has been uneven across countries (WIPO, 2010). In times of economic downturn, reduced business confidence and a fall in cash flows may prompt firms to file for fewer patents. Firms may opt for patent filings and renewals that focus on core technologies. The third decline was in 2019. A substantial decline in resident filings in China was the main driver of this decrease in the global total. Accordingly, to the statistics, Chinese domestic patent filings declined by 9.4% in the first half of 2019, while more outbound patents were filed by Chinese companies internationally. Over the years, China has become world number one in terms of quantity of patent filings. However, the prevalence of low-quality or "junk" patent filings in China, the country's intellectual property protection has been strengthened through a series of measures implemented by the China National Intellectual Property Administration (CNIPA) in 2019. Acknowledging the issues associated with low-quality patents, the CNIPA has taken steps to promote high-quality development of patents in China (Liang, 2012; Wininger, 2021). As a result, in the first half of 2019, the number of invention patent filings in China went down to 649 thousand, a decrease of 9.4% compared to 2018. This outlines the increasing importance of R&D as a determinant for business success through the proxy of increasing patent filings.

Figure 2.1: Patent Applications Worldwide



2.2 Top Patent Applicant Countries

This section indicates the statistics of top patent applicants in the US, Japan, Europe, and BRICS. Table 2.2 shows the top 5 patent applicants at USPTO from the year 2000 to 2019. Japan is on top for all the years with highest number of foreign patent applications in the US. China has replaced Germany in the year 2019 on second position. The UK is on third position in 2000 but it dropped down to fifth position for rest of the years.

Table 2.2: Top Five Foreign Patent Applicant Countries in the US					
Rank	***2000***	***2005***	***2010***	***2015***	***2019***
1	Japan (52883)	Japan (71994)	Japan (84017)	Japan (86359)	Japan (84435)
2	Germany (17706)	Germany (20664)	Germany (27702)	Republic of Korea (38205)	China (39055)
3	UK (7520)	Republic of Korea (17217)	Republic of Korea (26040)	Germany (30016)	Republic of Korea (36424)
4	Canada (6809)	Canada (8638)	Canada (11685)	China (21386)	Germany (30290)
5	France (6618)	UK (7962)	UK (11038)	UK (13296)	UK (14124)
Source: WIPO, March 2023					

Table 2.3 reveals the status of top five patent applicant countries in Japan from 2000 to 2019. Here the US, Germany, and Republic of Korea are on top three positions respectively for all the years except 2019. It shows their consistency in foreign patent filing. In 2019, China replaced Germany on second position, Germany and Republic of Korea dropped one position down. On fourth and fifth position it's changing within France, Netherlands, Switzerland China and Republic of Korea.

Table 2.3: Top Five Foreign Patent Applicant Countries in Japan					
Rank	***2000***	***2005***	***2010***	***2015***	***2019***
1	US (9466)	US (23811)	US (23183)	US (26501)	US (22867)
2	Germany (3593)	Germany (7929)	Germany (6794)	Germany (6430)	China (7947)
3	Republic of Korea (2625)	Republic of Korea (6845)	Republic of Korea (4872)	Republic of Korea (5222)	Germany (6207)
4	France (1555)	Netherlands (4303)	France (3425)	France (3369)	Republic of Korea (5634)
5	Switzerland (713)	France (3180)	Netherlands (2252)	China (2840)	Switzerland (2640)
Source: WIPO, March 2023					

Table 2.4 shows top five patent applicant countries at EPO. At EPO also top five positions are taken in 2019 by the US, Germany, Japan, China and France. If we see the data for 2000, the US is not in top five applicants. 2005 onwards the UK is not in top five patent applicants list. The above three tables shows that top five applicants are more or less same, only ranks are changing. Only China is a new addition to list 2015 onwards. It shows the significant contribution of China as upper middle-income country in patent application globally.

Table 2.4: Top Five Foreign Patent Applicant Countries in Europe

Rank	***2000***	***2005***	***2010***	***2015***	***2019***
1	Germany (20104)	US (32741)	US (39519)	US (42677)	US (46128)
2	Japan (17124)	Germany (23798)	Germany (27354)	Germany (24833)	Germany (26816)
3	France (6791)	Japan (21470)	Japan (21824)	Japan (21418)	Japan (22094)
4	Netherlands (4435)	France (8035)	France (9530)	France (10779)	China (12163)
5	UK (4359)	Netherlands (7799)	Switzerland (6742)	Switzerland (7096)	France (10231)

Source: WIPO, March 2023

Table 2.5 and 2.6 reflects the top five foreign patent applicant countries in BRICS (Brazil, Russia, India, China, and South Africa) in the year 2000 and 2019. We can see that the US, Germany, and Japan are filing highest number of patents in BRICS economies. Germany and Japan are also top foreign patent applicants in the US. Among BRICS countries, there is no emerging economy in the list of top foreign applicants due to weak innovation structure.

Table 2. 5: Top Five Foreign Patent Applicant Countries in BRICS 2000					
Rank	***Brazil***	***Russia***	***India***	***China***	***South Africa***
1	US (6191)	US (1298)	US (2271)	Japan (8300)	..
2	Germany (2050)	Germany (871)	Germany (829)	Japan (8300)	..
3	France (1050)	France (374)	Japan (787)	US (7503)	..
4	Japan (714)	Japan (320)	UK (359)	Germany (2578)	..
5	Sweden (577)	Sweden (266)	Switzerland (338)	Republic of Korea (1579)	..
Source: WIPO, March 2023 “..” data not available					

There is a significant growth of patent applications in BRICS countries from 2000 to 2019, it has caught the attention of researchers. It brings us to the question that what drives patent surge in these emerging economies. It also points a finger towards large number of MNCs coming to these countries bringing FDI. But what are the motivations to file patent in emerging economy need to be investigated at country and firm level.

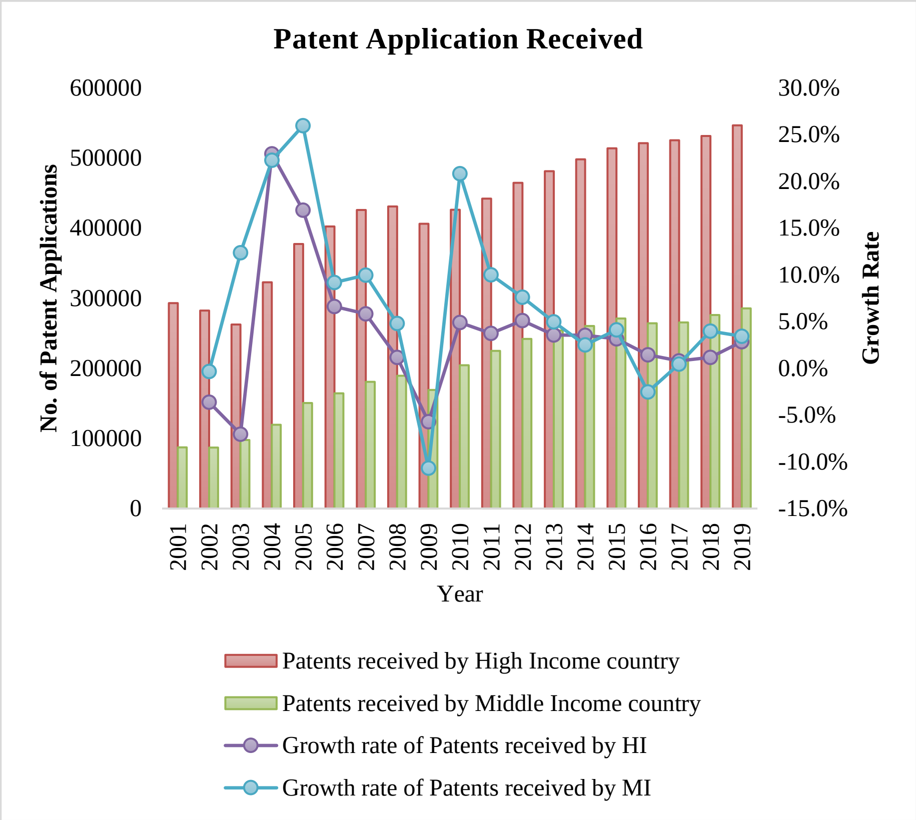
Table 2. 6: Top Five Foreign Patent Applicant Countries in BRICS 2019					
Rank	***Brazil***	***Russia***	***India***	***China***	***South Africa***
1	US (7555)	US (2862)	US (10405)	Japan (48867)	US (2056)
2	Germany (1750)	Germany (1364)	Japan (4853)	US (39450)	China (701)
3	Japan (1602)	Japan (1292)	China (3767)	Germany (16421)	Germany (479)
4	China (1219)	China (1071)	Germany (2754)	Republic of Korea (16019)	UK (392)
5	France (1133)	Switzerland (785)	Republic of Korea (2673)	France (4826)	Switzerland (322)
Source: WIPO, March 2023					

Without empirical evidence, the discussion on top patent applicant countries is incomplete. Our study aims to fill this gap by providing empirical evidence to better understand the international patenting activities of both developed and developing economies.

2.3 Patenting Activities of Different Country Groups

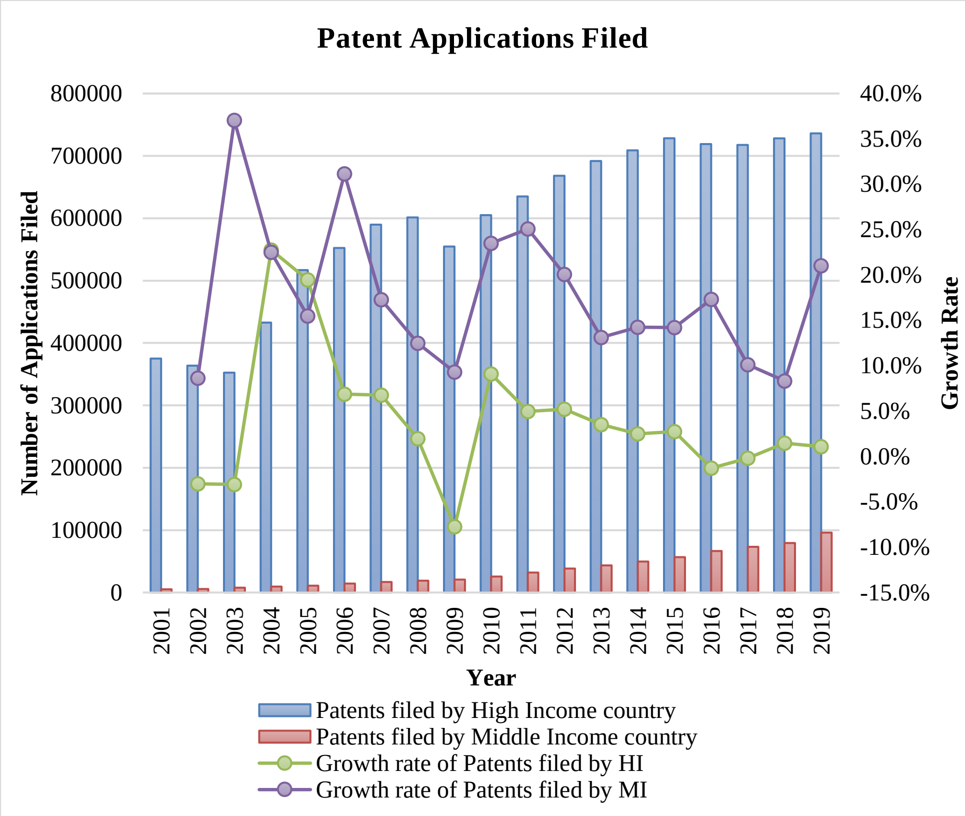
Further, we have analysed the patenting activities of the countries by income wise classification based on world bank definition i.e., High Income (hereafter HI) and Middle Income (hereafter MI) countries. Out of total 122 countries in our sample, 59 are HI countries and rest 63 are MI countries. We have selected our country sample on the basis of country filed patent (at least one patent in each year) at USPTO in minimum five years of the total time (2001 to 2019) of the study. Figure 2.2 shows the comparison between HI and MI countries as patent recipient from all other countries in the sample. It shows a continuous difference between the two income groups over the years. This constant difference shows a significant growth of MI countries in terms of patent application recipient. The intellectual property policies reforms by MI countries by 2005 as most of them become TRIPs compliant is a major reason of such growth. Though the growth rate of patent application received by HI income countries remained low in comparison to MI countries but that could be due to base effect where patents received by MI countries were just 30% of patents received by HI countries in 2001.

Figure 2.2: Patent Application Received



Patents filed by HI and MI country groups in all other countries in the sample also show similar trend (see Figure 2.3). The patents filed by HI countries are much higher than MI countries throughout the years. Also, patent filing by MI countries has grown with decent pace. This rise is noticeable after 2010. Though the difference between the number of patents filed by HI and MI country groups has widened over the years. Comparing the MI countries as source and recipient countries, they performed well as patent recipient countries. It is due to multiple factors such as IPR reforms, internationalisation of R&D by advanced economies, globalised and competitive markets, operationalisation of MNCs in emerging markets etc.

Figure 2.3: Patent Applications Filed



Further, we analysed the performance of HI and MI country subgroups as source and destination of patent applications for rest of the country groups. Figures 2.4 and Figure 2.5 displays patent received by HI (from HI and MI countries) and MI (from MI and HI countries) country subgroups. The patenting flow from MI to MI and MI to HI is significantly low while it is much higher in case of HI to HI. Though patenting from MI to HI shows an increasing trend from 2012 onwards. Patent application received by MI countries from HI countries has also increased significantly from 2001 to 2019. The possible explanation for these trends is that the developing economies spends less on R&D activities compare to developed economies therefore their innovative capabilities remain low which leads to low patenting (domestic and foreign both). In HI countries the share of non-resident patenting is dominated by other developed countries patent applications rather than the developing countries. As developing countries firms are technologically laggards and not able to compete with the highly innovative firms in the developed country market, they have less incentive to file patents in highly competitive country. On the other hand, the developed country firms are highly competitive, innovative and efficient to exploit developing countries' market. As a result, the share of patenting activity of developed country is high in the developing countries. Raghupathi and Raghupathi (2017) also presented similar results and stated that countries with low GDP per capita (middle and low-income countries) have a high percentage of patents owned by foreign residents because these countries rely on foreign collaboration to strengthen their resources and facilities for innovations. These cross-border collaborations often lead to patent ownership by foreign residents instead of local applicants. While developed economies with high GDP per capita have more local resources and talent, and therefore do not rely on foreign collaboration. This results in high proportion of patents owned by locals and a low proportion of patents owned by foreigners.

Figure 2.4 : Patent Applications Received from High Income Countries

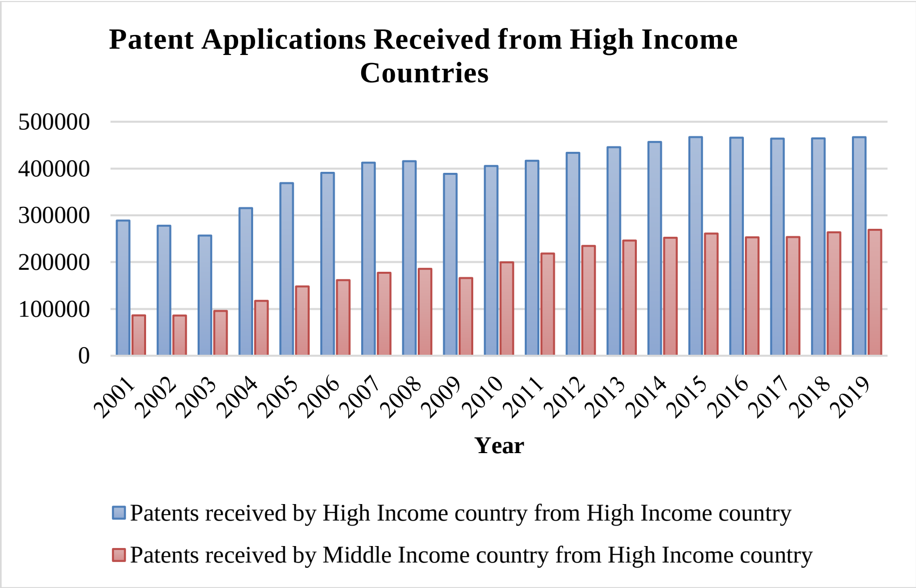


Figure 2.5: Patent Applications Received from Middle Income Countries

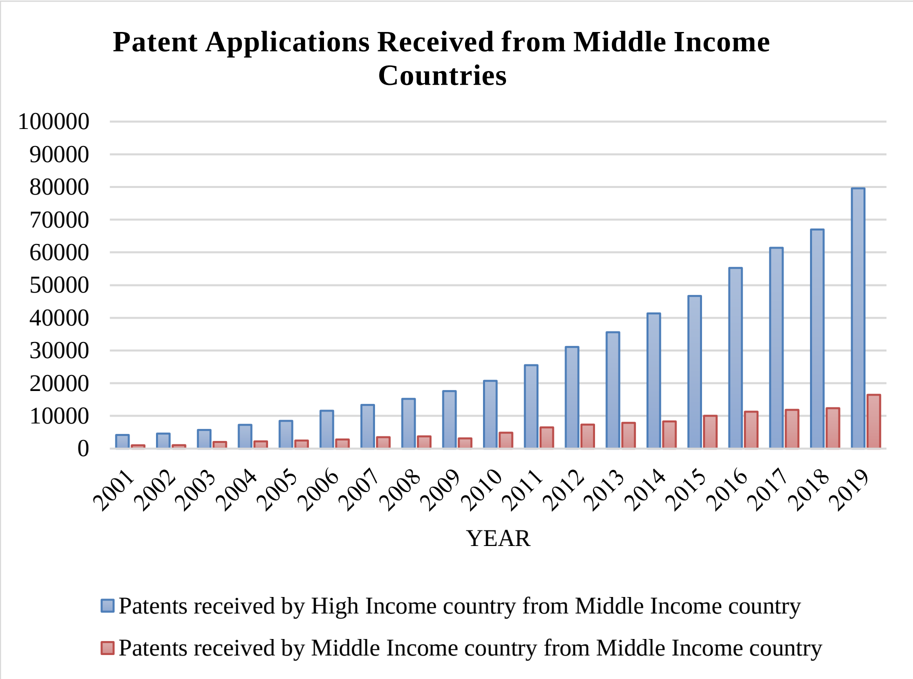


Figure 2.6 shows the growth rate of patent applications received by HI and MI countries. It indicates that patent applications received by HI countries from MI countries and MI countries from MI countries with higher growth rate than other two cases i.e., MI from HI and HI from HI countries. It shows that during 2001 to 2019, MI countries have originated patent applications with higher growth rate than HI countries. The higher growth rate of patent originating by MI countries is possibly associated with their GDP per capita growth rate which was higher in same period. The Figure 2.7 shows the GDP per capita growth rate of MI and HI countries from 2001 to 2019.

Figure 2.6: Growth Rate of Patent Applications Received

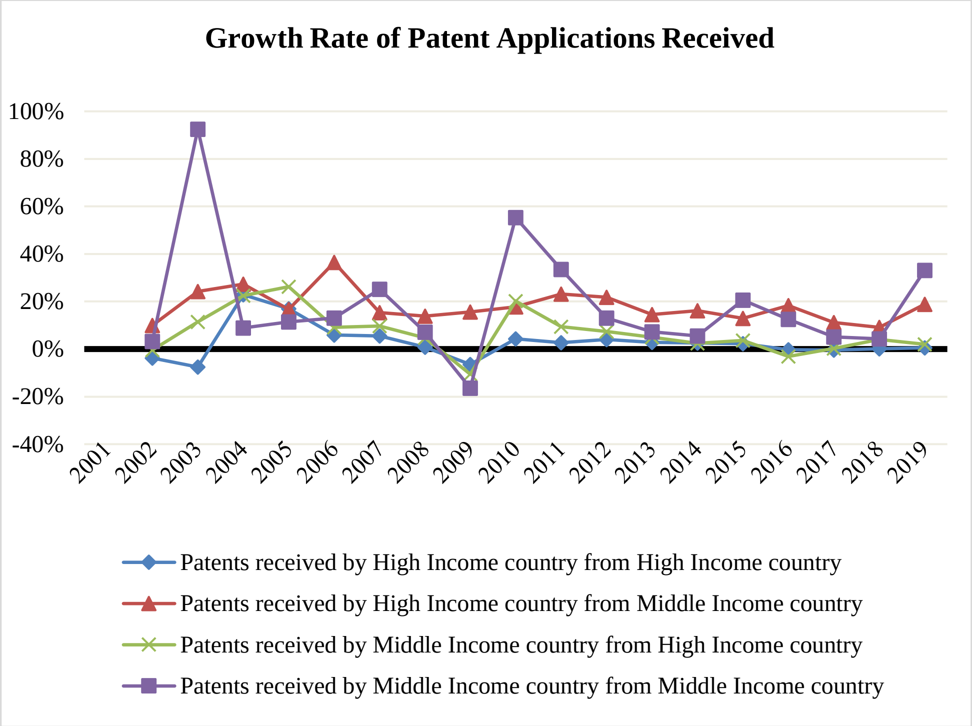
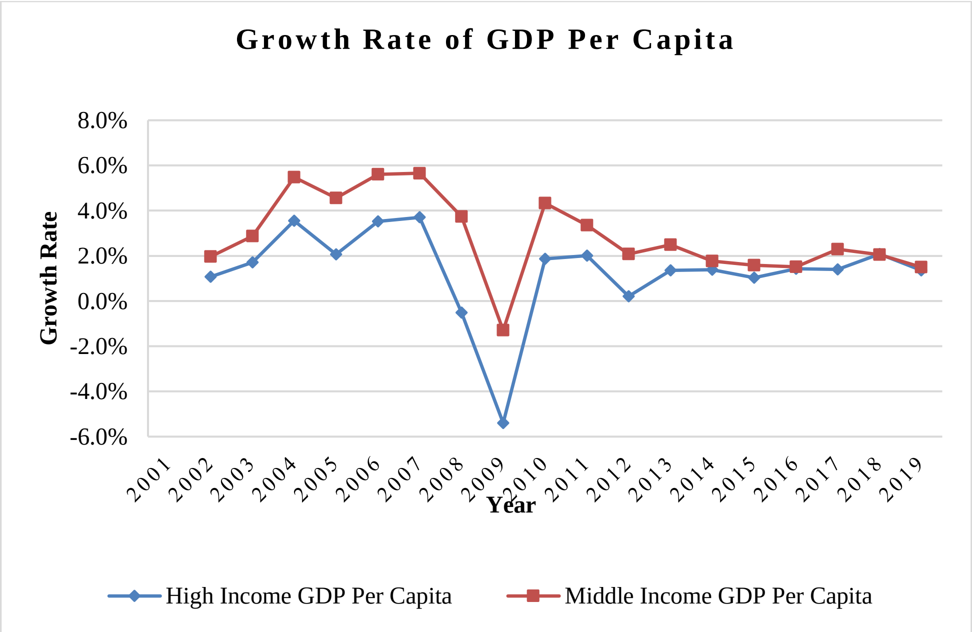
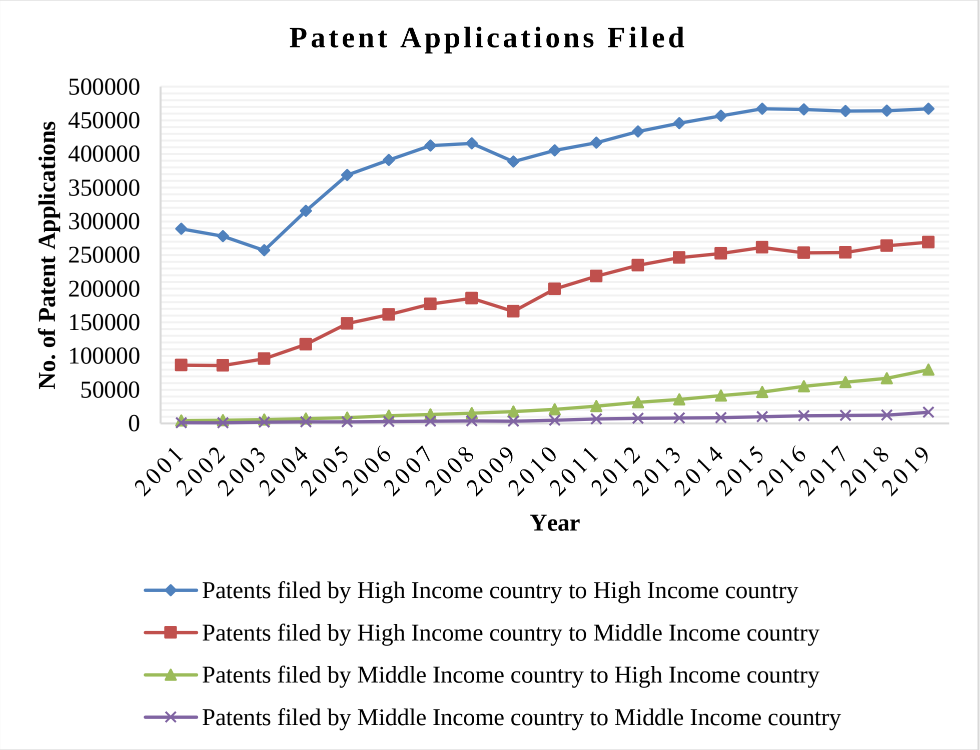


Figure 2.7: Growth Rate of GDP Per Capita



Further, Figure 2.8 displays that the patent flow from HI to HI and HI to MI is higher and other two groups (MI to HI and MI to MI). It shows that home country GDP per capita plays more important role than host country GDP per capita to drive patenting. Because patenting/R&D depends upon technological capabilities of the country where the technology was developed, and it is expected to be higher in high income countries.

Figure 2.8: Patent Applications Filed



2.4 Concentration of Non-Resident Patenting

This section presents the geographical concentration of patenting. Figure 2.9 shows the region wise distribution of patent applications received by different countries of the world. It indicates that around 80 percent of the total non-resident patent applications are received by East Asia and Pacific and North America region from all over the world. In East Asia and the Pacific, countries such as Japan, China, South Korea, and Singapore have become leading innovators in technology and manufacturing. These countries have developed world-class research facilities, robust supply chains, and skilled workforces that have attracted foreign investment and enabled them to create and patent new technologies. Similarly, North America has a robust technology sector and strong intellectual property laws that encourage innovation and entrepreneurship. The US, in particular, is the world's highest non-resident patent application receiving country.

Figure 2.9: Geographical Distribution of Patent Applications Received

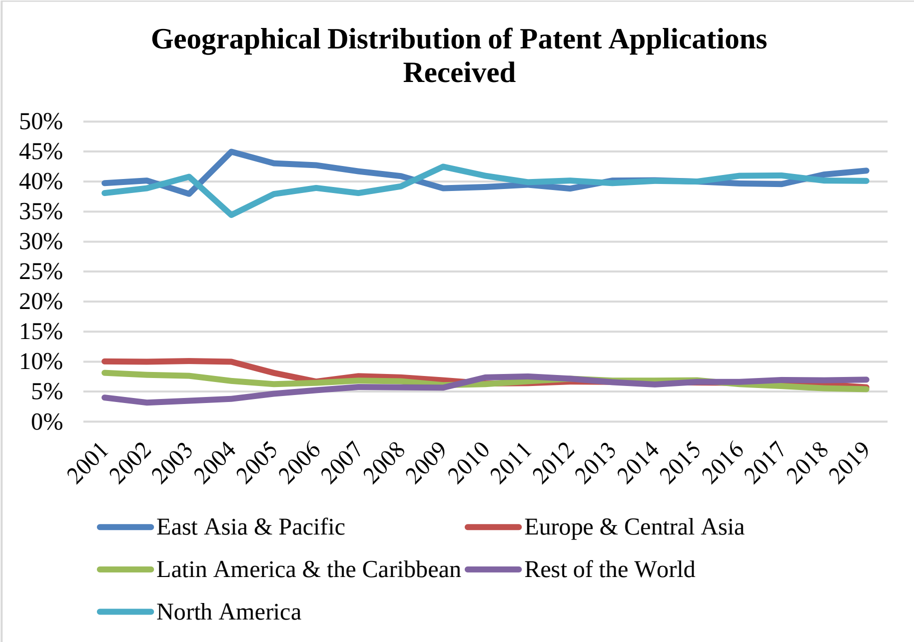
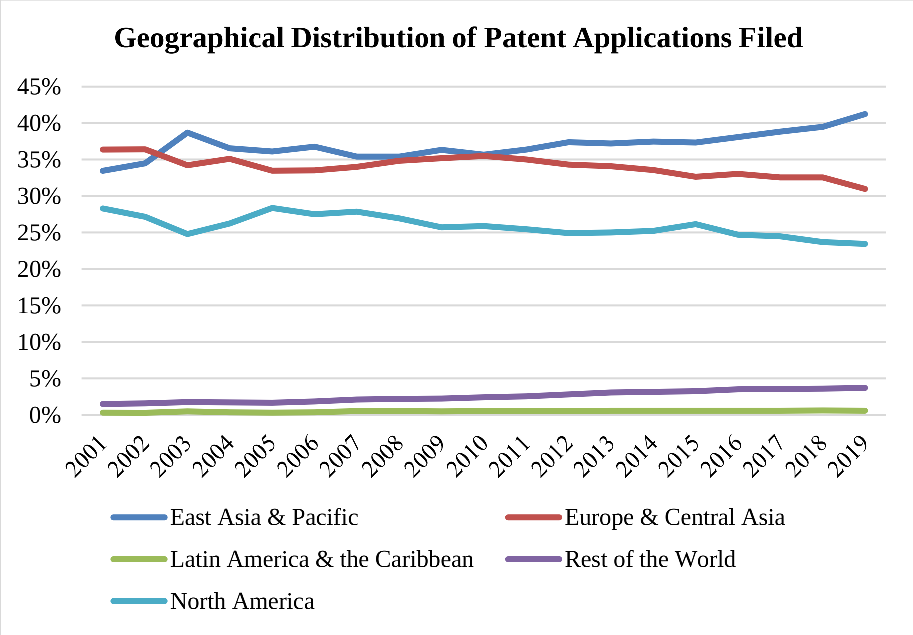


Figure 2.10 shows the geographical distribution of patent applications filed by our sample countries around the world. Our data indicates that patent applications are majorly originated from Europe and Central Asia, East Asia and Pacific, and North America. These three regions are the home to many of the world's leading companies in sectors such as technology, pharmaceuticals, and automotive manufacturing. These companies invest heavily in R&D and often file patents worldwide to protect their innovations. As a result, these regions have well-established ecosystem that foster innovation and provide the infrastructure and resources necessary to develop and commercialise new products and services. Here, Europe and Central Asia contributes significantly in originating patent applications while this region not receives much applications from other regions. Rest of the two regions contributes significantly both ways as patent application i.e., as a source and destination.

Figure 2.10: Geographical Distribution of Patent Applications Filed



Our data shows that since last two decades there has been a global boom in patenting activity because (i) increased importance of both technological innovation and knowledge-intensive trade as key drivers of national economic development (ii) there has been a trend towards strengthening and harmonization of patent institutions across nations and regions. This boom shows a significant shift in the worldwide balance between domestic patenting and international patenting towards international patenting. Therefore, international patenting has been increasing in importance. In 2010, more than 40 percent of all patent applications in the world's patent offices were from non-residents (Maurseth & Svensson, 2012). The international patenting plays a key role for technology diffusion because a patent in a specific country protects the inventor from imitators producing in that country and from outside imitators selling there. To get a wider geographical protection, the inventor has to apply for patent equivalents, i.e., parallel patents for the invention in several countries. The dominant trend of foreign patenting on a global scale raises two important questions that needs attention: What are the key influencing factors underlying international patenting activity? Does this affect the inventive capacity and productivity of recipient the country? We propose to address these questions in this doctoral dissertation.

Chapter 3

Literature Review

3.0 Introduction

The previous chapter is about the global patenting growth trends. It also gives detailed analysis of country wise foreign patenting data with graphical representation. It shows performance of High Income and Middle-Income countries in the sample as patent recipient and patent applicant countries.

This chapter reviews the literature concerning internationalization of patents including motives that affect the decisions to patent abroad and corresponding consequences for the host country. We explore these aspects while treating foreign patents as a measure of international technology diffusion.

3.1 Dimensions of International Patenting Literature

The field of cross-country patenting has garnered the interest of researchers from economics, law, and public policy (Maskus, 2000; Yang & Maskus, 2001). Further, we find that the studies based on international trade as well as international business focus on the international patenting. Evidently, in economics, international trade theorists emphasise on the drivers of patenting in terms of host country and home country factors and the impact of foreign patenting on trade, innovation, productivity, and growth (Egger & Merlo, 2007; Yang & Maskus, 2001). International business literature with resource-based view attempts to identify the motivations and strategies of multinational firms in protecting their innovations across countries (Danish et al., 2021; Dunning, 1988; Kogut & Zander, 1992). This literature is briefly outlined below though the thesis is based on international trade literature.

Studies on non-resident patenting have gained momentum after the works by Eaton and Kortum (1996; 1999). However, the growth rate of non-resident patents has overtaken the rate of resident patents since 1989 (Eto & Lee, 1993; Perkins & Neumayer, 2009). This growth rate was reached an average of 19% in 1990s (Yang & Kuo, 2008). Compared to the 8% average annual growth rate of the previous decade, this was a huge improvement. The increasing number of patent applications filed by non-residents with major patent offices like the USPTO, EPO, and JPO shows that this trend has continued into the modern era (WIPO, 2021).

3.2 Micro Economic Perspective of International Patenting: Understanding Firm Level Motivations

This section delves into empirical studies to shed light on why companies file for foreign patents and how it improves market access, technology transfer, and strategic positioning. Companies pursue international patenting for a variety of reasons. Studies show that these reasons include, establishing a foothold in new markets, securing licensing deals with local partners, establishing technological leadership, and discouraging potential competitors from entering the market. Firms can also use foreign patenting to protect their innovations from imitators in industries characterised by rapid technological change and intense competition. Understanding the motivations for foreign patenting can help policymakers and businesses better leverage intellectual property protection to promote innovation, technology diffusion, and economic growth.

3.2.1 Firm Level Determinants

From a micro econometric perspective, understanding firm-level motivations for international patenting is crucial for gaining insights into the dynamics of innovation and intellectual property protection in the global economy. Empirical studies have shown that firms engage in international patenting for various reasons, including market access, technology transfer, and strategic positioning (Belderbos et al., 2004; Chen et al., 2015; Hu & Jefferson, 2009). For example, firms may seek patent protection in foreign markets to gain a foothold in new markets or to secure licensing deals with local partners. Additionally, international patenting can help firms establish their technological leadership and deter potential competitors from entering the market. Soete and Wyatt (1983) said that firm's propensity to patent abroad depend upon their own degree of foreign involvement e.g., multinational corporations. It means that to the extent that MNC with a relatively high degree of foreign involvement decides its propensity to patent abroad. In other words, MNCs being more likely to engage in international patenting due to their global operations and access to cross-border knowledge spillovers (Hu & Jefferson, 2009; Lai et al., 2017).

Licht and Zoz (1998) observed that there is a tendency that firms will apply for more patents in the export destination country when there are more exports in a foreign market. For this analysis they used the application for German, European and U.S. patents by the German companies. Inkmann et al. (1998) created a trade-theoretical model of foreign patenting with the combination of relative factor prices, transportation costs and demand conditions. They examine the patenting behavior of German firms by adopting maximum-likelihood probit technique, their results demonstrated that trade variables, as captured by relative market sizes and relative wages, do not substantially contribute to the location choice of patenting.

MNCs are increasingly adopting a range of strategies to gain technological advantages and maintain their competitiveness in the global market. To achieve this, MNCs are required to engage in R&D activities across national boundaries, in addition to marketing and production (Gupta et al., 2015). Furthermore, MNCs often file patents in multiple countries to maximise their global intellectual property protection and gain a competitive advantage over local firms (Chen et al., 2015).

A study by Arora et al. (2016) focuses on UK innovators. The authors examine the relationship between openness to external knowledge and collaborative innovation on the one hand and patenting activity on the other. They find that firms that engage in collaborative innovation and are more open to external knowledge are more likely to patent their inventions. This study provides further evidence of the importance of knowledge spillovers and collaboration in driving innovation and patenting activity among firms.

Moreover, the decision to file for patents abroad may depend on a range of factors such as firm size, R&D intensity, industry structure, and country-specific institutional and legal environments (Chan, 2010; Hu, 2010; Huang & Jacob, 2014; Chang et al., 2018; Corchuelo & Suárez, 2016). For instance, larger firms with extensive R&D activities are more likely to engage in international patenting due to their greater capabilities to finance and manage complex patent portfolios. Similarly, firms operating in industries characterised by rapid technological change and intense competition are more likely to seek patent protection in foreign markets to safeguard their innovations from imitators. Additionally, the attractiveness of foreign markets and the strength of intellectual property rights regimes in different countries can also influence the decision to file for international patents.

Likewise, MNCs also have a greater capacity to finance and manage complex patent portfolios, which enables them to better exploit their innovative capabilities and generate revenues from licensing and technology transfer (Li & Wu, 2015). Additionally, MNCs can leverage their existing patent portfolios to negotiate better licensing deals and strategic partnerships with local firms, which can further enhance their technological competitiveness in the global marketplace (Belderbos et al., 2004).

Research and development (R&D) intensive multinational corporations (MNCs) invest heavily in innovation, and protecting their intellectual property through patenting is crucial for realizing returns on these investments. Studies have found that MNCs tend to patent not only in their home countries but also in foreign countries where they operate, to safeguard their innovations and secure market access (Licht & Zoz, 1998; Nerkar & Shane, 2007).

However, several determinants influence a firm's decision about international patenting. Imitation threats are a significant factor, as firms are more likely to patent in foreign markets where they face a higher risk of imitation and piracy (Grupp & Schmoch, 1999). Product market competition is another driver, as firms patent to gain a competitive edge over their rivals and strengthen their market position (Huang & Jacob, 2014). Finally, innovation quality also plays a role, as firms that generate higher-quality innovations are more likely to patent abroad to protect and monetise their inventions (Beneito et al., 2018). Further, Danish et al. (2021) study explores the relationship between innovation and internationalization in the Indian pharmaceutical industry, finding a feedback loop between exporting and innovative performance. The study suggests that firms should consider the dynamic interaction between innovative and exporting activities when making strategic decisions.

Researchers used firm-level data and econometric methods to identify the determinants of international patenting and their effects on innovation, productivity, and competitiveness (Hall et al., 2001; Li & Wu, 2015). Researchers were able to estimate the impact of international patenting on various firm outcomes, such as R&D investments, sales growth, and profitability, by using regression analyses and other statistical techniques. `

3.3 Macro Perspective on International Patenting: Understanding Country Level Contributing Factors and Ensuing Impact

The macro perspective on international patenting focuses on the contributing factors at the country level and the impact on economic growth and development. Human capital, R&D expenditures, foreign direct investment, trade openness, and intellectual property protection have all been identified as determinants of international patenting in various studies. These determinants differ across countries, as does their impact on international patenting. Understanding these factors can assist policymakers in developing policies that encourage innovation and economic growth. Furthermore, international patenting can help with technology transfer, spillovers, and knowledge dissemination, all of which can lead to increased economic growth and development. Understanding the macro perspective of international patenting is therefore critical for promoting national and global innovation, economic growth, and development.

3.3.1 Country Level Determinants

Foreign patenting is the process of filing a patent in a foreign country, which can be influenced by a variety of country-level determinants. These determinants can include factors such as economic development, intellectual property rights protection, and international trade agreements.

One of the primary determinants of foreign patenting is a country's level of economic development. Countries with more developed economies tend to have more resources and greater technological capacity, making them more likely to engage in foreign patenting. Research has shown that a country's level of income is positively correlated with the number of patents filed in foreign countries (Khan & Sokoloff, 2001).

Another important factor is a country's intellectual property rights protection. Stronger intellectual property rights protection can provide greater incentives for firms to invest in research and development, leading to increased foreign patenting. Countries with stronger intellectual property rights protection are also more likely to attract foreign investment in innovation (Blind & Jungmittag, 2004).

International trade agreements can also have a significant impact on foreign patenting. Participation in trade agreements can increase access to foreign markets, as well as provide greater protection for intellectual property rights. Research has shown that countries that are parties to international patent agreements tend to have higher rates of foreign patenting (Maskus, 2000).

In early studies, Eaton and Kortum (1996) pointed out that due to territorial nature of the intellectual property rights and extensive costs of international patenting the decision of where to patent affords information regarding where the innovators' ideas being used. This study is based on cross-section of 19 OECD countries to explain the number of patents taken by innovators of a country (source) in another country (destination), and the subsequent impact of such patents on relative productivities of source and destination countries. The results suggest that foreign patenting is larger with smaller distance between two countries, larger ability of the destination to absorb technology (as measured by the level of human capital), and higher relative productivity of destination.

Patenting inventions on a global scale is a crucial component in the process of transferring technological know-how from one nation to another, as well as a driver of innovative activity. In his study, Park (1999) places a strong emphasis on the significance of international patenting as a means of disseminating new products and processes. In addition, patent applications submitted by foreign investors have the potential to disclose new information, which may result in knowledge spillover effects for the host country. The intellectual property rights regime of the country that will be receiving the patents is an essential factor in the decision-making process. According to Park (1999), a strong intellectual property rights regime has a positive and substantial impact on international patenting.

Yang and Kuo (2008) study cross-patenting activity of 30 countries between 1995 and 1998 and finds that the variations in the levels of outward-bound international patenting between countries is attributed to trade-related influences namely exports and outward foreign direct investment. Existing trade and investment activities necessitate legal protection for the products in the host countries (Yang & Kuo, 2008). Archontakis and Varsakelis (2011) focus on the flow of US patents to 27 OECD countries and using a gravity model, highlights that the mass of patenting activity in the US and the destination country are significant factors explaining the behaviour of the US patenting activity abroad. Interestingly, the study mentions about the role of technological gap between the countries in the knowledge diffusion, however, it does not operationalise the variable in the empirical model. Nevertheless, earlier studies have shown that the level of economic development in a country has a positive correlation with the number of patents filed in other countries (Khan & Sokoloff, 2001).

The existing studies use R&D expenditure of a country to capture the input in its knowledge production function that leads to output in terms of domestic and international patenting. Evidently, outward patenting by a country must be linked to the overall technological capabilities of a country. Further, technological gap among the countries is likely to influence international patenting. These aspects gain relevance as not only most developed economies are involved in cross-patenting but developing economies are also major partners (both as source and recipients) in the trade of ideas. However, technological capabilities of the source country and technological gap of the recipient country as key determinants of cross-country patenting have not been explored in the empirical studies. The thesis proposes to address this research gap. More details are given in the next chapter.

3.3.2 Implications of Non-Resident Patenting on Host Country

3.3.2.1 Positive Implications

Foreign patenting has important implications for the host country's technological and economic progress. Foreign patents can facilitate the diffusion of new technologies and knowledge spillovers from inventors in the patent applications, leading to innovation and productivity gains for the host country (Park, 1999). This can be particularly beneficial for developing countries that may lack the resources or capabilities to develop new technologies on their own.

Eaton and Kortum (1996; 1999) concluded that productivity growth in other countries is driven mainly by the innovation activities of leading research economies such as the US, Japan, and Germany. Their research suggests that these countries have the greatest impact on technological progress in the world, and that their patenting activities are critical in fostering global innovation.

Nonetheless, not all countries can take advantage of knowledge embodied in patent applications filed by non-residents. Peri (2003) identifies constraints faced by the developing countries in realising knowledge spillovers from foreign patents. His study reveals that developing countries with low levels of human capital that are located far from knowledge centres could hardly gain from non-resident patents unless their technology bases were significantly improved. This highlights the importance of technology transfer and capacity building for developing countries, to enable them to benefit from non-resident patenting activities.

In contrast, Xu and Chiang (2005) confirmed that both developing countries and technology laggard countries enjoyed technology spillover from the non-resident patents filed by leading industrial countries. Their study supports the notion that non-resident patents can facilitate technology diffusion and knowledge transfer across borders, providing benefits to a wide range of countries.

After Eaton and Kortum, other studies conducted by Perkins and Neumayer (2009), Baldwin and Hanel (2003), and Rivera and Kline (2000), have found that the number of patents held by non-residents is a better indicator of the effects that international technology diffusion has on the productivity of countries than the amount of money invested in R&D. These studies provide evidence that the origin and destination countries of non-resident patents provide information about external sources of knowledge to local firms. Additionally, these studies provide evidence that foreign influence in local innovation can be measured by the number of patents of a particular technology that originate from a particular country.

Another set of studies highlight the consequences of technology diffusion by international patenting using non-resident patent data (Frietsch & Schmoch, 2010; Nam & Barnett, 2011; Moussa & Varsakelis, 2017; Archontakis & Varsakelis, 2017). Kotabe (1992) stated that foreign patents help to improve the technological strength and prosperity of domestic firms and, consequently, of a domestic economy. He examined how foreign patents affect the economic vitality (measured by GNP) of each country (US, Japan, Germany, and Britain) using the binomial lag estimation method. This study shows that the infusion of foreign technology has become increasingly important for the improved economic vitality of all the countries except Japan given the existing domestic technological infrastructure. The role of foreign technology for Japan's economic growth was at peak in 1974. Since then, the Japanese economy has been driven by a rapid improvement in its domestic technological infrastructure.

The above discussion suggests that non-resident patenting affects domestic R&D. However, domestic R&D may also have a positive impact on innovation by non-residents through various channels. First, domestic researchers may publish in international scientific journals, and that can be accessed and used by researchers from other countries, leading to innovation by non-residents. Second, domestic R&D activities can facilitate collaboration between domestic and foreign researchers, which can lead to joint innovation. Third, domestic R&D activities can result in the creation of patents which can be licensed or sold to non-resident innovators. Lastly, domestic R&D activities can spur global competition, which can encourage non-resident innovators to develop new products or technologies in order to compete in the global market. A study by Ghimire and Paudel (2019) analysed this opposite relationship i.e., impact of domestic R&D on innovation by non-residents (non-resident patenting) in OECD countries using panel data for the period 1996-2015. Their study shows an interesting result that domestic R&D alone impedes innovation by non-residents. However, when R&D interacts with FDI in the host country, it produces the opposite results (impacts non-resident patenting positively). It means that R&D and FDI have a substitution effect on innovation by residents whereas they have a complementary effect on innovation by non-residents. Using foreign patent data to measure technology diffusion and its impact has various advantages. First, it clearly shows the origin and destination country of the technology which helps to provide information about external sources of knowledge to local firms. Second, the number of patents of a particular technology from a particular country provides evidence that may provide the magnitude of the foreign influence in local innovation. Thus, non-resident patents are essential for characterizing international technology diffusion (Mccallum, 1995; Archambault, 2002; Hafner, 2008; Frietsch & Schmoch, 2010).

3.3.2.2 Negative Implications

There are, however, potential disadvantages to foreign patenting for host nations. Foreign patents, for instance, may create entry barriers for domestic firms, thereby limiting competition and possibly impeding innovation and economic growth (Maskus, 2000). Foreign firms often have more financial resources, technical capabilities, and access to global markets, making it challenging for local firms to compete. Additionally, non-resident patenting in host countries can allow foreign firms to gain exclusive rights to use and commercialise a technology or product, which can prevent domestic firms from entering or expanding in the market, hindering competition and innovation. Entry barriers for domestic firms lead to limiting competition, thereby reduce employment opportunities, and limit access to essential goods and services. Non-resident patenting may also lead to dominance of foreign firms in terms of economic power, creating an uneven playing field for domestic firms. This can ultimately result in a dependency on foreign technology and products, limiting the ability of domestic firms to develop and innovate.

Moreover, foreign patent owners may impose high licencing fees or restrict technology transfer to the host nation, resulting in reduced access to essential technologies and stifling local innovation efforts (Roffe, 2007). This can be especially troublesome for nations that rely heavily on imported technology.

3.4 Research Gaps

We find that there is still a lack of clarity regarding the ways in which non-resident patenting influences R&D investment in different ways in developed and developing countries. The past literature mostly comprises empirical analysis of firm level determinants of innovation and productivity focusing on developed countries, which are mostly global technological frontiers. However, non-resident patenting was not studied in initial innovation input and output models. Studies dealt with innovation patterns and the determinants of innovation at the macro level and that including developing economies are scarcer. Except for research studies discussed in above sections, many questions related to R&D expenditure and productivity remain unanswered both at the firm and country level. Exploring the wide coverage of existing literature, we conclude that previous studies do not have clarity on how differently non-resident patenting influence R&D investment in developed and developing countries in terms of productivity. Clarity on this issue can bring a different set of policy recommendations regarding innovation and technology policies according to the development status of the country.

In the context of the impact of foreign patenting on the host nation, studies demonstrate that non-resident patents have a significant impact on the technological and economic development of the host nation. Patents granted to non-residents can enhance the technological prowess and prosperity of domestic firms and economies. Foreign patents also provide local businesses with external sources of knowledge, which can boost innovation and productivity in the host nation. However, the impact of non-resident patents may vary based on the country's level of development, technological infrastructure, and the interaction between R&D and FDI. Thus, understanding the impact of non-resident patenting on the host country is essential for developing policy recommendations for innovation and technology.

Chapter 4

Conceptual Paradigm, Data and Econometric Issues

4.0 Introduction

The previous chapter discussed the extensive literature in the field of international business and economics. It mainly focuses on the factors driving non-resident patenting from both (host and home) countries' perspectives. Further it discusses the influence of non-resident patenting on determinants of innovation and total factor productivity in the host countries. The chapter also identifies the research gaps that the present dissertation attempts to address. In continuation, this chapter builds the conceptual framework and hypotheses to be empirically verified. It also presents the methods used to examine the drivers and impact of non-resident patenting on host countries along with data, its sources and construction of variables.

4.1 Determinants of Non-Resident Patenting

4.1.1 Technological Capabilities of Home Country

Technological capabilities (TCs) of a country are a complex array of skills, technological knowledge, and organizational structures that are required to operate a technology efficiently and accomplish technological change. Kim (2001) stated that technological capabilities refer to the ability to make effective use of technological knowledge in the production, engineering, and innovation. Therefore, TCs can be built and accumulated by the process of technological learning. Patent as an outcome of the knowledge production function of an economy, as espoused by Griliches (1990), cannot merely depend upon the R&D expenditure. Particularly, the selected few inventions that are patented abroad reflect on the overall technological capabilities of a country. In the context of a developing country, there is a possibility that some firms may patent abroad instead of patenting at home. Take for instance, a case of India, where software patents are not allowed *per se*. In such cases, we need to take a broader representative of the investments made in innovation in terms of financial resources and human capital. Accordingly, we compute a technology index[8] for each country instead of merely using R&D expenditure as used by previous studies like Yang and Kuo (2008). Wignaraja (2012) also shows that even for firms, instead of R&D, technology index which is a broad measure of innovation plays role in determining their exports.

In terms of measurement, international agencies have constructed indices measuring country level technological capabilities while emphasising one or another aspect of TCs. These indexes are World Economic Forum (WEF) Technology Index (WEF, 2001; 2002; 2003; Furman et al., 2002), the United Nations Development Program (UNDP) Technology Achievement Index (TAI) (UNDP, 2001; Desai et al., 2002), United Nations Industrial Development Organization (UNIDO) Industrial Development Scoreboard (UNIDO, 2002; Lall & Albaladejo, 2001), and the Science and Technology Capacity Index developed by the RAND Corporation and associated partners (Wagner et al., 2004). Another indicator of technological capabilities is developed by Archibugi and CoCo (2004) called as ArCo index. Such indicators of technological capabilities are needed to understand why some countries have a more innovative performance than others. Recently, Panda et al. (2020) also constructs a technology effort index by using five innovation indicators (including both input and output indicator of innovation) through principal component analysis (PCA). All the above indices include some common variables like the use of patents as an indicator of technology creation, ICT indicators for technological infrastructure and diffusion, and tertiary education in science and engineering as an indicator of human skills. Furthermore, all the indices are based on weights of different sub-indexes. Study by Westphal et al. (1990) is a pioneer work that uses Technology Index

[8] TCs measurement related literature and concerns are discussed below.

(TI) as a measure of technological capabilities and other studies use the different variants of this tool (Dominguez & Brown, 2004; Iammarino et al., 2008; Romjin, 1997).

4.1.2 Technological Gap

The Technology Gap Trade Theory

The initial focus of the technological gap trade theory revolves around the varying levels of innovation between countries, which serve as the fundamental drivers of international trade patterns. This principle held true in the earlier works on technological gap analysis (Posner, 1961; Freeman et al., 1963; 1965; Hirsch, 1965; Hufbauer, 1966) and in explorations of the intersection between trade and technology (Findlay, 1978; Krugman, 1979). A study by Soete (1981) concluded that considering international patenting as a technology-output indicator, this choice effectively incorporates both the concept of possessing an exclusive monopoly over "productive knowledge" and the temporary nature of that monopoly right. This alignment not only aligns seamlessly with the theoretical foundation of technological gap trade theories but also carries broader trade-related welfare implications (Johnson, 1970; 1976; Borkakoti, 1975).

The Technology Gap Theory

In economic history, the idea of countries that are followers catching up with leaders was conceptualized by Alexander Gerschenkron, as the ‘advantages of relative economic backwardness’. Gerschenkron (1962) argues that developing nations possess a unique advantage through their state of relative backwardness, which affords them the opportunity to access and adopt technologies and best practices that have already been developed by more advanced countries. The gap provides the economic incentive to catch up, while the political process drives institutional innovation. Wider gaps create stronger incentives to leap forward. However, later theoretical studies explained that technological laggard countries may face a disadvantage of backwardness because of their limited absorptive capacity, and thus the existing technology gap may impede learning in the international technology diffusion (Aghion et al., 2005; Castellacci, 2011; Popp, 2006). Fagerberg (1994) and Keller (2004) highlighted that global technology gaps can stem from the unequal distribution of knowledge across nations. The international technology diffusion is characterized by non-uniformity and incompleteness: technological advancements originating from specific countries might have a greater impact on one nation compared to another, and this diffusion may only extend to a limited subset of countries. This phenomenon is clearly mirrored in the data related to international patenting: the flow of international patents tends to be concentrated within developed economies, with relatively scant patent filings in less developed nations. Consequently, when weak patent rights impede the process of patenting, they inadvertently serve as obstacles to the diffusion of technology, further intensifying global technology gaps. Building on the works of Benhabib and Spiegel (1994), Coe and Helpman (1995), Eaton and Kortum (1996), and Coe et al. (1997), Xu and Chiang (2005) highlight three aspects of international technology diffusion. (i) International trade as a carrier of foreign technology embodied in capital goods. (ii) International patenting as a technology diffusion channel. (iii) Postulate that the technology diffuses in disembodied form from technology-leading countries to technology-following countries at a rate that increases with the technology gap between them and with the human capital level of the technology-following countries.

Further, Xu and Chiang (2005) investigate international technology diffusion through trade and patenting in a sample of 48 countries for the period 1980 – 2000. They used the technology GAP variable, the ratio of US TFP to the sample country's TFP. The results indicated that countries with a larger technology gap against the US (higher GAP) grow faster in TFP and the speed of technology catch-up increases with the level of human capital. In the study conducted by Park (2013), the investigation revolves around assessing the impact of strengthening and harmonisation of patent rights on the stimulation of international patenting and its potential role in reducing technology gaps. This study revealed that enhanced patent reforms, particularly those concentrated on encouraging international patenting, are unlikely to result in substantial reductions in technology gaps between developed and developing countries. In this study, international TFP differences are used as measures of technology gaps.

Gao (2022) carries out separate analyses for technological leading and lagging countries and compares the impact of international patent inflows on innovation capacity between leaders and laggards as recipient countries. This study argues that the positive impact of international patent inflows on innovation capacity would be stronger for technology-leading countries, which suggests that international patent inflows may enlarge the existing technological gap between leaders and laggards.

We have pointed out that in the existing literature, the technology gap is studied as a dependent variable. We have not come across any previous research that directly investigates the influence of the technology gap on other dependent variables. Consequently, our approach in this thesis is to conduct a thorough review of related literature that can assist us in identifying potential pathways and assessing the impact of the technology gap specifically on inward foreign patenting. Past studies have not explicitly examined this relationship in the manner that we intend to explore in this thesis. For a comprehensive overview of the potential channels related to this research, please refer Table 4.1 below.

Table 4. 1: Channels by which Technological Capabilities (TC) and Technology Gaps (TG) affect Non-Resident Patenting (NRP)		
Country Groups	**Technological Capabilities**	**Technology Gap**
High Income (HI) countries	*Positive effect on outward NRP:* Innovation Leadership Knowledge Transfer Global Market Expansion *Negative effect on outward NRP:* Intellectual Property Risks Competition and Loss of Market Share	*Positive effect on inward NRP:* Access to market Accelerated Innovation International Collaboration *Negative effect on inward NRP:* Strong Intellectual Property Rights Small market size Loss of Competitive Advantage Dominance of Large firms
Predicted Sign	Positive	Ambiguous
Middle Income (MI) countries	*Positive effect on outward NRP:* Increased Innovation Increased Competitiveness International Collaboration *Negative effect on outward NRP:* Resource Limitations Technology Gap Intellectual Property Challenges Lack of Market Access	*Positive effect on inward NRP:* Technology Transfer Reverse Innovation Competitive market Cost-effective R&D *Negative effect on inward NRP:* Low investment in innovation Weak Intellectual Property Rights Challenges
Predicted Sign	Positive	Ambiguous

TCs determine the inventions that firms are likely to patent in other countries while technological gap with the other nations plays a role in determining which countries to reach out. The key argument here is that each nation has an absorptive capacity for patent-sensitive goods in terms of their market. As Adler (1965) mentions absorptive capacity is the ability of an economy to utilise and absorb external information and resources. Cohen and Levinthal (1990) refer to it as the ability to acquire, adapt, transform, and determine knowledge which influences organization or country's innovation and competence. We argue that though GDP per capita can capture the purchasing capacity of the nation, the low technological gap between the patent origin and recipient country highlights the ability and responsiveness of the consumers of the recipient country for the patent-sensitive good. Accordingly, if the technological gap is low (high) between the two countries we may witness high (low) patenting between such a pair.

Geronikolaou and Mourmouri's (2015) applied PROMETHEE II (Preference Ranking Organisation Method for Enrichment Evaluations) ranking method to identify the technological distance (gap) instead of geographical distance between two countries. They find that effects of technological gap on technology trade cannot be unambiguously determined, and it depends on whether the source country is a low or a high-ranking country. This study has adopted the weighting method to rank the technology variables such as R&D, patent applications and venture capital investment. Assigning an appropriate weight to each variable is a complex task and more often, we end up with faulty measure. Thus, in this thesis, we construct a technology index instead of giving ranks based on technology-related variables.

From the above discussions, we form following two hypotheses regarding the effects of technological capabilities and technological gap on foreign patenting:

H_1: *Home country's technological capability is positively related to the patents applied in other countries.*

H_2: *Technological gap between two countries is inversely related to the patents applied in other countries.*

4.2 Understanding the Impact of Non-Resident Patenting

4.2.1 Advent of CDM model

The connection between sources of knowledge (e.g., R&D) and the country's economic growth has been studied by different approaches in the literature of knowledge economy. R&D is also known to be an important contributor to technological progress and, hence, economic growth (Mansfield, 1981; Torrero, 1990). The production function approach by Griliches (1979) was the first attempt to measure the contribution of R&D to firm's economic growth. He introduced total factor productivity as a function of past R&D investments, physical capital, human capital, firm size, and industry specific factors. Further, Griliches (1980) pointed out that R&D as innovation input only contributes to innovative capabilities, not to the productivity of the firm or country. The positive impact of R&D on growth and productivity has been examined by various theoretical (Arrow, 1962; Romer, 1986; 1990; Grossman & Helpman, 1991; Aghion et al., 1998; Proudman & Redding, 1998) and empirical studies (Coe & Helpman, 1995; Coe, Helpman & Hoffmaister, 1997; 2009; Griliches, 1998; Cameron et al., 2005; Kafouros, 2005; O'Mahony & Vecchi, 2009; Bravo-Ortega & Marin, 2011) at the firm, industry and country level. Teitel (1994) found that patents granted to residents are positively related to the R&D expenditures and stock of scientists and engineers using the production function approach for a group of 68 countries. Fostering industrial R&D helps to improve national innovative capacity which is important to ensure long-run economic growth of the country.

Pakes and Griliches (1980) reported the relationship between patent applications and R&D expenditures, based on data for 121 large U.S. companies covering eight years period. The study showed that there is a statistically significant relationship between a firm's R&D expenses and the number of applied and granted patents. The link between R&D and patent in this study was termed as "knowledge production function". The regression results using this model had issues like selectivity and simultaneity bias.

In Pakes and Griliches model, due to the selectivity issue it excludes firms that do not invest in R&D. However, the firms that are not innovative in formal ways can in fact generate new knowledge or acquire it on the market in the form of technologies, rights, licenses, and so forth. The exclusion of these firms at the level of empirical analysis can lead to a significant sampling error (Griffith et al., 2006). Another complicated factor in the analysis is endogenous R&D costs. It means that firms decide to invest in innovations based on expected returns (Griliches, 1979; Jefferson et al., 2006).

In 1998, Crépon, Duguet and Mairesse (CDM approach) highlighted the fact that it is innovation output that matters for the productivity of a firm not innovation input (R&D) through the CDM approach. They attempted to correct undesirable effects of selectivity and simultaneity bias and the complexity of innovation processes that have affected many past R&D and patent studies. This comprehensive model considers the firm's decision about innovations, the amount of investment in innovations ("innovative input"), the innovative outcome ("innovative output"), and the economic effect on the company's bottom line. The inclusion of the firm's investment decisions in the analysis makes it possible to consider firms that are not innovative according to formal criteria and to avoid bias due to sampling error. The authors used a comprehensive approach to the econometric analysis of their model, which is able to take into account the sampling error and simultaneity that can lead to the endogeneity of certain variables (e.g., R&D investment and innovation proxies such as patents), as well as the fact that the indicators may vary in their statistical nature (they may be continuous, integral, or ordinal).

At the macro-level, R&D investment, innovation, productivity, and per capita income reinforce each other and lead to sustained long-term growth (Hall & Jones, 1999; Rouvinen, 2002). Several studies provide evidence of the relationship between R&D, innovation, and productivity at the firm level in case of industrialised countries (Griffith et al., 2004; Griffith et al., 2006; OECD, 2009; Mairesse & Mohnen, 2010). In most previous theoretical models, the link between R&D and economic growth was recognised by an equilibrium equation in which resources allocated to the R&D sector stimulates the total factor productivity (TFP) growth.

4.2.2 Conceptual Idea of CDM Model

CDM model is a pioneer work done by Crepon et al. (1998) (CDM stands for initials of three authors Crepon, Duguet, and Mairesse) to address the problem of assessing both impacts of research on innovation output and impacts of research and innovation output on productivity. The original model comprises four equations (i) selectivity equation which show if firm invests in research or not (ii) innovation input (R&D) equation which shows determinants of level of innovation input (iii) innovation output (patents) equation which presents determining factors of innovation output including R&D investment (iv) productivity equation shows the impact of R&D, patents, and other determinants of total factor productivity. The presentation of the model in terms of the equation is given in section 4.2.3.

The error terms in the system of Equations (i)–(iv) can be correlated so that they are linked to strong endogeneity and simultaneity in the model. The authors of CDM model solve this problem by carrying out their assessment in two stages. In the first stage, the system equations are estimated in reduced form by disclosing the parameters of the preceding equations. Also, each equation is solved using the most relevant method considering the type of dependent variable: (1) and (2)— Tobit II, (3a)—quasi-maximum likelihood method (quasi-MLE) with negative binomial remnants, (3b)—ordinal probit model, (4a) and (4b)—method of ordinary least squares (OLS) with a robust covariance matrix. During the second stage the obtained auxiliary parameters are used for the simultaneous estimation of the structural model using the asymptotic method of least squares (ALS). To justify the use of an econometric tool (ALS) Crepon et al. (1998) evaluated the model using simpler methods (such as Maximum Likelihood Estimation, two stage Least Squares Method and Ordinary Least Squares method). A comparison of the assessments showed that the system of the equations (i)–(iv) contains a big issue in which the simultaneity and sampling errors are correlated, so they can reinforce each other. The use of alternative methods makes it possible to get inappropriate results due to the endogeneity of R&D expenditures and sampling bias.

Literature shows that the basic CDM model application is exclusively for firm level studies. We build on this and propose the use of CDM model for country level innovation (both inputs and outputs) and productivity indicators for this thesis. This model is a system of four non-linear equations with limited dependent and count data variables. It also deals with selectivity and simultaneity in this system using Heckman's selection model and reduced form of the independent variables by disclosing the parameters of the preceding equations respectively.

4.2.3 Introducing Non-Resident Patenting in CDM Model

An economy emphasises R&D and entrepreneurship for innovation-driven growth (Koh & Wong, 2005; Rostow, 1959; WEF, 2012; Raghupathi & Raghupathi, 2019). R&D efforts are considered as an important input to the innovation economy while patents reflect innovation output. Past literature reflects a significant gap between developed and developing economies in terms of R&D investment and technology development. An international technology transfer is an effective way to narrow down such technology gap between the countries. Technology transfer is a process by which commercial technology is disseminated from one industry to another, and/or among different economies (Rosegger, 1996). International technology transfer can take place either by direct channels (market-mediated) or indirect channels (nonmarket). Direct channels include trade, FDI, licensing, joint ventures, and cross border movement of personnel. Indirect channels include departure of employees, temporary migration, information in foreign patent applications, and test data (Rosegger, 1996; Maskus, 2004). The flow of non-resident patents, i.e., patents applied by foreign institutions or individuals, represents one of the most important channels of international technology transfer (Hu et al., 2016). International patents are the indicator of countries' best inventions due to their higher probability in developing into a full-fledged innovation than the domestically filed only patents (Eaton & Kortum, 1996; 1999; Furman et al., 2002; Paci et al., 1997). Considering the above fact, many studies have applied cross-country patenting data in the measurement of national innovation capability (Paci et al., 1997) and productivity growth (Caviggioli, 2011).

Past studies show that the benefits from foreign R&D investment can be transmitted through different channels such as FDI, trade, cross-country patents etc. and affect domestic R&D investment decision. However, the relation between foreign technology inflows and domestic R&D investment is ultimately an empirical question. Results of the existing literature are inconclusive, and evidence varies from case to case. Based on the above discussion we raise the following hypothesis.

***H*$_3$*: Non-resident patenting is positively related to the host country's innovation input (R&D intensity)*

There are other reasons whereby non-resident patenting affects resident patenting of a host country directly: (a) expansion of R&D activities by MNCs in host countries lead to increase in competence levels. Therefore, host country researchers become involved in more advanced R&D projects, some of which will eventually result in patents. These patents will often be filed by a team of researchers, some of whom are residents of host countries while others work for the MNC in the home base or in other industrialised countries. Gerybadze and Merk (2014) identified structural changes and the extent of generation of new knowledge by studying the development of host-country patenting with contributions of local inventors (b) patent applications filed by foreign applicants is a major source of technology diffusion to local firms (Maskus, 2004). The local firms get the opportunity to study the underlying technology in those applications and invent new products or processes parallel to that technology avoiding infringement (Sharma & Saxena, 2012). The local inventors may file patents for such inventions. Therefore, the following hypothesis is proposed:

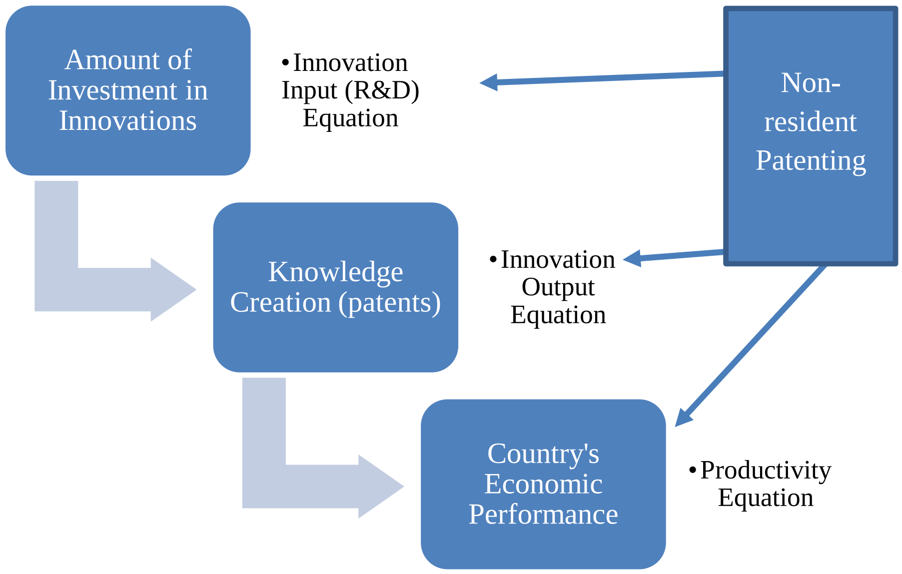
H_4*: Non-resident patenting is positively related to the host country's innovation output (Resident patenting)*

Existing literature suggests that in the case of technologically advanced countries most of the innovation activities are reflected in R&D and patent related information. Thus, it is feasible to capture the effect of foreign technology influence on developed economies in terms of their innovative capabilities and productivity. Previous studies have found a positive relationship between TFP and technology spillovers, such as patents from foreign countries to domestic ones (Li & Xu, 2004). For example, Li and Xu (2004) found that technology spillovers from foreign countries have a significant positive impact on China's TFP growth. But in other developing countries not all type of innovations may be captured by R&D expenditure and by the patenting. Due to limited capacity of investment, they may be making some incremental changes to improve productivity of the country such as upgrading their production processes. So, if that is the case, we are including the foreign patenting in productivity equation separately. Thus, we hypothesise that:

H_5: *Non-resident patenting is positively related to the host country's productivity (Total factor productivity)*

Following (refer Figure 4.1) is the diagrammatic presentation of our model (augmented CDM model) based on the above discussion:

Figure 4.1: The variant of CDM Model based on Crepon, Duguet, and Mairesse (1998)



4.3 Econometric Specifications, Variables, and Data Sources

4.3.1 Sample

This study comprises two different country groups. The first group contains 122 countries to examine the determinants of foreign patenting for a period. These 122 countries have been selected based on their patenting activity at US patent office from year 2001 to 2019 as USPTO is the highest non-resident patents receiving offices in the world. We have selected our country sample based on a country filed patents (at least one patent in each year) at USPTO in minimum five years of the total time (2001 to 2019) of the study. The second group includes 188 countries to analyse the impact of foreign patenting on host countries. These 188 countries are selected as per the availability of the data (dependent variables' data). In the first group out of 122 countries 59 are high income countries and rest 63 are middle income countries. In the second group out of 188 countries 66 high income countries, 47 upper middle-income countries, 50 lower middle income and 25 lower income countries. The income-based categorisation of the countries is taken from the world bank website. The estimations are first applied on full samples and then split samples of the countries. The period of both the studies is 2001 to 2019.

4.3.2 Foreign Patenting Equation: Variables and Data Sources

For the empirical purpose, we used a panel data technique. To analyse the relationship among technological capabilities, technological gap, and cross-country patenting we apply gravity model framework using negative binomial regression model. Following is our regression equation:

$$FORPAT_{ijt} = b_1 x_{1it} + \varepsilon_{ijt} \tag{1}$$

where x_{1i} is a vector of explanatory variables, b_1 , the associated coefficient vector and ε_{ijt} an error term. Here, our dependent variable, FORPAT denotes the number of patent applications the home country i seeks in host country j. For independent variables, we build on the literature to introduce control variables and include technology index and technological gap, which are the prime factors for the study. The detailed reasons for introducing these variables have been given above while the construction of these variables is given later. Continuing with our definitions, TI refers to technology index, IPR stands for index of patent rights, GDPPC is gross domestic product per capita for each country, Contig refers to contiguity (common geographical borders) between two countries (host and home countries), ComnLang stands for the common language between two countries, ColTies refers to past colonial ties between the two countries and EPOHH denotes the membership of both the home and the host country at European Patent Office (EPO). Out of 122 sample countries, 38 of them are the contracting states of EPO.

The description along with the rationale for the independent variables introduced in equation (1) is as follows:

Technology Index (TI): Based on earlier discussion, in this thesis, we include country level variables to construct a technology index based on Panda et al. (2020). There are four variables, where two of them represent input indicators: R&D expenditure as % of GDP, researchers in R&D per billion population. The remaining two variables represent output indicators: the number of patent application by residents and the number of published scientific and technical journal articles. Scientific and technical journal articles and patents capture output produced due to investments made in R&D. A country's production of new technology is captured by its patents, and it is an important indicator of the technological activities of firms in the country (Basberg, 1987; Archibugi & Planta, 1996). The last two variables (published articles and resident patents) are standardised by real GDP to adjust for the economic size of the country. We do not include non-resident patents as used by Panda et al. (2020) since it is the dependent variable in the current study. This study computes a technology index by simple average method after normalizing the variables. For each country, each of these four variables is standardised using the following technique (Lall, 2003; Archibugi & Coco, 2004):

$$\text{Index} = \frac{X_i\,Value - Minimum\,X_i\,Value}{Maximum\,X_i\,Value - Minimum\,X_i\,Value}$$

We then took the average value of the four standardised variables to construct the technology index. The technology index lies between 0 and 1 where values close to 1 indicate intensive innovation activity (index values for all countries given in Appendix B). Here, equal weights are assigned to each variable while computing the technology index because of following reasons: (1) in the literature there is no clear evidence that any of these variables should be given greater importance than other in determining country's level of technological development (2) assigning equal weights simplify the computation of the index and make interpretation easier, since each variable would contribute equally to the final score (3) it is also important since index is used for comparative purposes, such as benchmarking a country's performance against other countries.

This study uses an index based on Ginarte and Park (1997) and Park (2008) to quantify the level of patent rights (PRs) protection across countries[9]. Index of patent rights by Ginarte and Park (1997) and Park (2008) is available for 122 countries. The index provides a score that reflects a given country's overall level of patent rights and restrictions at a given point in time. The index ranges from 0 (no patent system) to 5 (strongest level of protection). The index is the unweighted sum of five separate scores for coverage (patentable inventions; membership in international treaties; duration of protection; enforcement mechanisms; and restrictions). For all the five parameters there are several conditions, the index value is based on the scores obtained by each country by satisfying the number of policies related conditions under each parameter. Further it is constructed with the gap of every five years therefore the index score changes if there is any policy change during those five years. The index value is available from 1960 to 2015 quinquennially (e.g., 1960, 1965, 1970…….2015). Thus, the index given in 2000 will be used for another five years till the new index values are computed with the assumption that no major regulatory changes in the patent policy of a country are introduced during the interim period. Since the present study starts from 2001, we have used the latest index given in 2000 for the years 2001 to 2004 and new index values for 2005 which are used for the next five consecutive years (2005 to 2009). Studies by Sweet and Maggio (2015) and Shin et al. (2016) used Park's IPRs Index (available quinquennially) to measure the strength of patent rights protection with other variables that are continuous across time.

In equation (1), we use the host country's index of PRs and the interaction of TI home and index of PRs of host country. The purpose of using interaction variable is capturing the combined effects of the

[9] Index of patent rights by Ginarte and Park (1997) and Park (2008) is available for 122 countries (available on Prof. Walter G Park's website) from 1960 to 2015 quinquennially.

TCs of a source country and the patent rights (PRs) of the destination countries on the cross-country patenting of the source countries. This study explicitly considers this new channel of the impacts of TCs on outward non-resident patenting, namely the direct impact of TCs and their indirect impact through their interaction with the host country's level of PRs.

Technological gap is measured as a difference of each country in terms of technology index (TI_i value) from the country with highest technology index (TI_{max} value) in a particular year. It has been calculated by following formula:

$$\text{Technological Gap} = TI_{Max(t)}\, Value - TI_{it}\, Value$$

This study has taken GDP per capita (constant 2015 US$) to measure the economic size of countries (Barro, 1996). GDP is also used to proxy the overall market size, which affects incentives to patent (Allred & Park, 2007). It has been used for host and home country in both the equations. Apart from these, we used three more gravity variables as dummies, these are: contiguity (1 if both countries are contiguous (shared border) and 0 otherwise); common language (1 if a language is spoken by at least 10% of the population in both countries and 0 otherwise); and colonial ties (1 if both countries have any colonial ties in the past or present and 0 otherwise). Lastly, a variable to capture the member states of European Patent Office (1 if both countries are members of EPO and 0 otherwise). Based on above information we construct our foreign patenting equation as follows:

$$FORPAT_{ijt} = \beta TI_{it} + \beta_1 LnGDPPC_{jt} + \beta_2 LnGDPPC_{it} + \beta_3 IPR_{jt} + \beta_4 TechGap_{ijt} + \beta_5 Contig_{ij} + \beta_6 ComnLang_{ijt} + \beta_7 ColTies_{ijt} + \beta_8 IPR_{jt} TI_{it} + EPOHH_{ijt} + \pi_{ij} + \pi_t + \varepsilon_{ijt} \qquad (2)$$

Here, i = home country (i= 1, 2,3, ……35) t = time (in years) j = host country. π_{ij} represents the country pair fixed effects which is specific to the country pairs and common to all the years and π_t represents the time fixed effects which is specific to year *t* and common to all country pairs. Table 4.2 provides variable definitions, and data sources. We use panel data analysis to quantify the effect of technology index and technological gap on foreign patenting and in turn its influence on technology trade. The patent count data (patent applications by non-residents) collected from WIPO statistics database were missing in case of many countries due to data reporting issue at WIPO either by filing office or origin country office. We have treated those data points as missing while applying regression because replacing the missing values by zero or minimum value one can deflate the real effect.

Table 4. 2: Variables Definition, and Data Sources

Variable Name	Definition	Data Source
$FORPAT_{ijt}$	Number of patent applications the home country *i* seeks in host country *j* (patent applications by non-residents) obtained from WIPO statistics database using following filters: Total patent applications (direct and PCT national phase entries) and count by filing office and applicant's origin	WIPO statistics database, WIPO IP Statistics Data Center
TI_{it}	Technology index of home country	World Development Indicators, World Bank
$LnGDPPC_{it}$	Log of GDP per capita of home (patent application applicant) countries (constant 2015 US$)	World Development Indicators, World Bank
$LnGDPPC_{jt}$	Log of GDP per capita of host (patent application recipient) countries (constant 2015 US$)	World Development Indicators, World Bank
IPR_{jt}	Index of Patent Rights of host	Ginarte and Park (1997), Park (2008), Prof. Walter G Park’s website (index values available till 2015)
$TechGapTI_{ijt}$	Difference in terms of TI from highest TI country to any other country in the group	World Development Indicators, World Bank
$Contig_{ij}$	1 if both countries are contiguous (shared border) and 0 otherwise	CEPII (The Centre d'Études Prospectives et d'Informations Internationales)
$ComnLang_{ijt}$	1 if a language is spoken by at least 10% of the population in both countries and 0 otherwise	CEPII (The Centre d'Études Prospectives et d'Informations Internationales)
$ColTies_{ijt}$	1 if both countries have any colonial ties in the past or present and 0 otherwise	CEPII (The Centre d'Études Prospectives et d'Informations Internationales)
$EPOHH_{ijt}$	1 if both countries are member states in European patent office and 0 otherwise	European Patent Office website (as per date of accession)
$IPR_{jt}TI_{it}$	Interaction of IPR of host and TI of home country	

4.3.3 CDM Model: Variables and Data sources

We use Crepon et al. (1998) approach of CDM (initials of three authors Crepon, Duguet, and Mairesse) model to revisit the innovation-productivity relationship based on macro level data. Following is the CDM model framework comprising four equations as we assume that not all countries in the sample invest significantly in R&D:

(i) **Sample Selection Equation:** The first equation depicts the country's innovation behaviour. We rely on Heckman's two step sample selection model. It accounts for the fact that the country has invested in R&D in that particular year or not. We assume that there exists a k_i^* as a latent dependent variable for country i given in the below equation (3a).

$$k_i^* = b_0 x_{0i} + u_{0i} \tag{3a}$$

where x_{0i} is a vector of explanatory variables, b_0, the associated coefficient vector and u_{0i} an error term, and where k_i^* expresses some decision criterion, such as the expected present value of the country GDP accruing to research investment. We observe that the country invests in research if k_i^* is positive or greater than zero, (provided x_{0i} contains an exclusion restriction/selection variable, which is the case for all our equations in this analysis).

(ii) **Innovation Input Equation:** The equation (3b) determines the size/level of the investments that country makes in innovation activities. It determines the innovation input k_i. We measured k_i as the accumulated costs of innovation. It has been estimated by using Heckman's two step selection model as a dependent variable is continuous and bounded. In this case, these are investments in innovation that cannot take a negative value. It can be presented as:

$$k_i = b_1 x_{1i} + u_{1i} \tag{3b}$$

Here, x is the vector of explanatory variables of innovation input i.e., R&D investment (R&D expenditure as a percentage of GDP), b is a vector of coefficient and u is the error term.

(iii) **Innovation Output Equation:** It links the R&D investment and innovative output of the country. The innovative output of the country can be proxied by the number of patents filed by residents n_i within the country and in a foreign country.

$$n_i = E(n_i \backslash k_i, x_{2i}, u_{2i}, a_k, b_2) = exp\,(a_k k_i + b_2 x_{2i} + u_{2i}) \quad (4)$$

Here, x is the vector of explanatory variables of innovation output (patents), a and b are vectors of coefficient and u is the error term. The above function (4) is estimated using negative binomial regression model.

(iii) **Productivity Equation:** It is a country's total factor productivity q_i equation depends on the result of actual innovation output. In fact, this is a Cobb–Douglas transformed production function with a knowledge capital factor. Depending on the innovation output proxy (i.e., patent applications by residents), it can be evaluated as follows:

$$q_i = a_i ln\,(n_i) + b_3 x_{3i} + u_{3i} \quad (5)$$

Here, x is the vector of explanatory variables of total factor productivity of a country, a and b are vectors of coefficient and u is the error term. The above equation (5) is solved using the method of ordinary least squares (OLS).

It is not possible that all type of innovations particularly in developing countries may be captured by R&D expenditure and by the patents because they may be doing some small technical improvements, incremental changes in their processes, frugal innovations due to influence of foreign knowledge which are not reported anywhere etc. Thus, their impact will not reflect in R&D and patent equations. A study carried out by Kim at al. (2009) on South Korean manufacturing industry shows that non-resident patent applications are more influential on the increase in productivity than resident patent applications. Thus, we are including the foreign patenting in productivity equation separately.

In this thesis, the explanatory variables used in the CDM model includes R&D expenditure as a percentage of GDP, school enrollment, secondary (% gross), patent application count by non-residents (per million), patent application count by residents, GDP per capita (constant 2015 US$), index of patent rights by Park, net inflows of foreign direct investment (% of GDP) and trade openness. Whereas dependent variables include R&D dummy, R&D expenditure as a percentage of GDP, patent application count by residents and total factor productivity. These variables are used to understand the relationship among non-resident patenting, innovation and productivity in developed and developing countries. The equation wise variables are discussed below:

a) Determinants of Innovation Input

The aim of our study is to identify the factors that impact R&D investment for country *i* in year *t*, measured as R&D expenditure as a percentage of GDP. We examine four factors: (1) international technology diffusion, which suggests that foreign R&D activities transmitted through non-resident patents (patent applications by non-residents per million) may benefit domestic R&D investment (Bebczuk, 2002; Okabe, 2003; Funk, 2003; Bhattacharya & Bloch, 2004; Matsubara, 2005; Yang et al., 2019); (2) patent rights protection, which argues that stronger patent protection mechanisms in a country lead to higher R&D investment, as proxied by the Index of Patent Rights by Park (Varsakelis, 2001; Park, 2001; Park & Wagh, 2002; Furman et al., 2002; Hu & Mathews, 2005; Wu et al., 2007). However, some researchers suggest that patent protection is a costly process and may not be effective for promoting inventions for all countries (Klemperer, 1990; Green & Scotchmer, 1995; Encaoua et al., 2006). (3) Income, proxied by GDP per capita, is suggested to be closely related to R&D investment (Jacob, 1966; Braconier, 2000; Furman et al., 2002; Teitel, 1994; Ginarte & Park, 1997; Hu & Mathews, 2005). (4) Trade openness led to greater R&D investment in both developed and developing countries (Glass & Saggi, 1998; Hu & Jefferson, 2009).

Selection of Exclusion Restriction Variable

In addition to above variables, we include one exclusion restriction variable in the selection equation to deal with the selectivity bias i.e., school enrolment, secondary (% gross). An exclusion restriction variable must be correlated with the independent variables, but uncorrelated with the error term in the model. Our approach in selecting the exclusion restriction variable for R&D investment was based on the criterion that this variable should demonstrate a certain threshold of developmental progress. During the initial stages of variable selection, we conducted a thorough assessment of potential explanatory and exclusion restriction variables. We dedicated significant effort to conducting an exhaustive survey of literature and methodologies to guide our selection of these variables. Here school enrolment, secondary (% gross) is a suitable instrument variable because it influences the level of R&D in a country through its impact on the availability of skilled workers and researchers, as well as the level of technological development.

Education represented by secondary school enrollment, can be an important determinant of a country's overall human capital and innovation capacity. Countries with higher levels of education might have a greater ability to engage in R&D activities, leading to a potential correlation between secondary school enrollment and R&D. More expenditure on education encourages more school enrolment, likely to have more scientists and engineers and require more R&D investment (Bebczuk, 2002).

We further observed that the existing literature shows that the availability of resources in a country plays a crucial role in industries’ decision to invest in R&D. Countries with stronger educational abilities tend to draw more R&D funding from US-based MNEs (Sanyal, 2004). In this study, the indicator of a country's human capital is represented by the ratio of enrolment in secondary schools and anticipated that a higher level of secondary education within a country would result in increased R&D investments by MNEs.

Nonetheless, Raghupati and Raghupati (2017) discover that despite Poland and Slovenia boasting elevated rates of educational enrolment, they do not secure positions among the leading innovative nations. This underscores the notion that a nation's substantial investment in educational enrolment does not inherently guarantee a corresponding positive impact on the country's volume of R&D investments. Consequently, the existing literature indicates that education stands as a pivotal factor influencing a country's choices regarding R&D initiatives. However, it is equally acknowledged that the influence of education might not uniformly extend to shaping the actual magnitude of R&D investments. Therefore, we have chosen the three potential variables that represent the human capital status of a country (1) Educational attainment, Doctoral or equivalent, population 25+, total (%) (cumulative) (2) Researchers in R&D (per million people) and (3) Secondary school enrolment.

For the first variable, we found very less data as for many countries most information was missing. The second variable, researchers in R&D (per million people), is directly linked to R&D expenditure as one of its components (current). The third variable secondary school enrolment represents the human capital, which is one of the main determinants of economic development and plays a crucial role in the technology progress of countries (Zhu et al., 2018). Higher level education contributes directly to economic development making workers more productive, and indirectly leads to the creation of knowledge, ideas, and technological innovations (Pradhan, 2009). Baldacci et al. (2005) found a positive linkage between school enrollment rates and GDP growth in developing countries. Acemoglu and Zilibotti (2001) argue that the potential for productivity rooted in the deployment of technology depends on the skills of the workforce in a particular economy. Developed countries have many skilled workers and are, therefore, in a better position compared to developing economies to reap the benefits associated with new technologies. Accordingly, we incorporated secondary school enrolment as an exclusion restriction variable for the following reasons: (i) Secondary school enrolment is part of the broader education system that eventually feeds into higher education institutions and research organizations. (ii) Higher education with a specialisation in a particular field highly depends upon secondary education. A well-educated workforce is essential for conducting advanced R&D activities. Countries with a higher percentage of educated individuals are more likely to have a skilled labor force capable of contributing to R&D efforts. (iii) The data availability is better in comparison to any other alternate variable.

b) Determinants of Innovation Output

Our dependent variable for the innovation output equation is the count of patent applications by residents, which is a commonly used indicator in literature (Pavitt, 1985; Griliches, 1990). Our key independent variable is non-resident patenting (patent applications by non-residents per million). In addition, we include several control variables such as R&D expenditure, the Index of Patent Rights, GDP per capita and FDI. Recent economic theory also suggests that patents are policy instruments that promote innovation and diffusion, and thus may have endogeneity issues with R&D investment. Therefore, while applying CDM model we used reduced form of R&D investment variable to deal with the simultaneity problem.

c) Determinants of Total Factor Productivity: To study the determinants of Total Factor Productivity (TFP), we assume a traditional Cobb-Douglas production function, which is a function of countries' physical capital, labor force, and human capital. TFP is defined as the growth of output that cannot be explained by the relative contributions of capital and labor and can be considered as "technical progress in its broadest sense" (Solow, 1957). We use TFP data from Penn World Tables (PWT) 9.0 (Feenstra et al., 2015) as our dependent variable.

Our key independent variable is the count of non-resident patent applications (patent applications by non-residents per million). Controls include reduced form (lagged variables) of R&D expenditure and resident patent applications, FDI, index of patent rights and trade openness, which we expect to have a positive impact on TFP.

4.3.3.1 Total Factor Productivity and Its Estimation

Total Factor Productivity (TFP) refers to the growth of output that is not explained by the relative contributions of capital and labour and can be considered as “technical progress in its broadest sense” (Solow, 1957). The growth of TFP is a broader measure of innovation used in literature (Ortega & Peri, 2012; 2014a; 2014b; Alesina et al., 2013). Kathuria et al. (2011) stated that TFP is defined as the ratio of output (or value added) to a weighted sum of the inputs used in the production process.

The concept of Total Factor Productivity (TFP), its measurement and interpretation have evidenced enormous scope for researchers after the initial work of Abramovitz (1956) and Solow (1957). Lipsey and Carlaw 2001 stated that there are three different views on what TFP is. The initial view considers that TFP is the measure of the rate of technical change (Law, 2000; Krugman, 1996; Young, 1992). The second view (Jorgensen & Griliches, 1967) believes that TFP measures only the free lunches of technical change, which are mainly associated with externalities and scale effects. The third view is highly skeptical whether TFP measures anything useful (Metcalfe, 1987; Griliches, 1995).

Past studies mostly follow the methods of TFP measurement given in Solow's 1956 and 1957 articles**.** Based on these articles, the two commonly used methods to calculate TFP are discussed in the literature. First, growth accounting method uses an aggregate production function to relate measured inputs to measured output. Any output growth not associated statistically with the growth in measured inputs is assumed to result from technological change. Second is the index number method that does not require aggregate production function. It calculates TFP by dividing an index of real GDP by an index of factor quantities used during the production process. While this is straightforward calculation method and only uses output and input indices, this method is valid only when one industry is compared across countries. Based on the index number method, Penn World Table 9.0 provides TFP estimates for 182 countries of the world. The Penn World Tables is a leading source of data for National Income Accounts related variables converted to international prices. It allows valid comparisons of GDP series among countries and is highly suitable for long term analysis.

We obtained data of TFP from the Penn World Tables (PWT) version 9.0 (Feenstra et al., 2015). We utilised the TFP index from the PWT dataset due to several reasons. First, TFP is calculated using real GDP that considers differences in the terms of trade across countries. Second, TFP for each country is measured relative to the TFP of the US. Third, the method used in PWT version 9.0 as compared to previous versions accounts for all countries' average hours worked. All these features of the TFP index provided by PWT dataset make it more accurate for this kind of analysis.

The TFP estimates from the PWT are used to make cross-country comparisons of economic performance. The PWT uses a production function approach, which is a form of growth accounting, to measure TFP. The production function relates output to inputs of capital and labor and TFP is estimated as the residual of the production function after accounting for the contributions of capital and labor. The growth accounting method in the PWT calculates TFP by subtracting the contribution of capital and labor inputs to output growth from the observed growth rate of output. The remaining residual is attributed to TFP, which captures all other factors that contribute to output growth, including technological progress, efficiency improvements, and changes in the quality of inputs. In this study we use the level of (relative) TFP.

For the level of (relative) TFP, we use the estimate provided in Penn World Table (PWT) 9.0, labeled *rtfpna* (Feenstra, Inklaar, & Timmer, 2015). This series is obtained by setting the TFP level of 2011 equal to 1, and then computing the remaining TFP levels backwards and forwards by applying the TFP growth rates. The TFP growth rates are obtained implicitly through the following equations:

$$\frac{RTFP_{jt}^{NA}}{RTFP_{jt-1}^{NA}} = \frac{RTFP_{jt}^{NA}}{RTFP_{jt-1}^{NA}} / Q_{jt,t-1},$$

Where, $Q_{jt,t-1} = \frac{1}{2}\left(LABSH_{jt} + LABSH_{jt-1}\right)\left(\frac{EMP_{jt}}{EMP_{jt-1}} \frac{HC_{jt}}{HC_{jt-1}}\right) + [1 - \frac{1}{2}\ (LABSH_{jt} + LABSH_{jt-1})]\left(\frac{RK_{jt}^{NA}}{RK_{jt-1}^{NA}}\right)$ (6)

$RTFP^{NA}$: TFP level, computed with RGDPNA, RKNA, EMP, HC and LABSH

$RGDP^{NA}$: Real GDP at constant national prices

RK^{NA}: Capital stock at constant national prices

EMP: The number of people employed

HC: Human capital based on the average years of schooling from Barro and Lee (2013) and an assumed rate for primary, secondary, and tertiary education from Caselli (2005)

LABSH: The share of labour income of employees and self-employed workers in GDP

j: country, and t: year

Table 4.3 provides variable definitions and data sources. In our dataset patent data has some limitations. The patent count data (patent applications by residents) collected from WIPO statistics database were missing in the case of many countries due to data reporting issue at WIPO by filing office. We have treated those data points as missing while applying regression because replacing the missing values by zero or minimum value one can deflate the real effect. The data of total factor productivity have been collected from Penn World Tables (PWT) 9.0. The details about the method used for calculating the TFP is discussed below. The TFP data for most of the low-income countries included in the sample is not available. Therefore, the impact of foreign patenting on TFP of low-income countries cannot be estimated in separate regression. Data for the rest of the variables is collected from world development indicators by world bank.

Table 4. 3: Variables and Data Sources		
Dependent Variables	**Variable Details**	**Source**
DRD	R&D Dummy – 1 if a country investing in R&D otherwise 0.	Created by Authors based on R&D expenditure
RDexp	R&D expenditure as a percentage of GDP	World Development Indicators by World Bank
PatAppR	Number of patent applications by residents	WIPO statistics database
TFP	Total Factor Productivity	Penn World Tables 9.0 (Feenstra, Inklaar, &Timmer 2015)
Independent Variables		
PatAppNR	Patent application count by non-residents (per million)	WIPO statistics database
SchoolEnrol	School enrollment, secondary (% gross)	World Development Indicators by World Bank
GDPPC	GDP per capita (constant 2015 US$)	World Development Indicators by World Bank
IPR	Index of patent rights by Park	Ginarte and Park (1997), Park (2008), Prof. Walter G Park's website (index values available till 2015
FDI	Net inflows of foreign direct investment (% of GDP)	World Development Indicators by World Bank
TO	Trade openness, (sum of exports and imports of goods and services as percentage of GDP)	World Development Indicators by World Bank

Based on the above framework and variables our final model is structured below. For the full name and definition of each variable refer Table 4.3. Equations (7a), (7b), (8), and (9) presented below are the extended version of equations (3a), (3b), (4), and (5) respectively.

The selection equation:

$$DRD^{*}_{it} = b_0 PatAppNR_{it} + b_1 GDPPC_{it} + b_2 IPR_{it} + b_3 TO_{it} + u_{it} \quad (7a)$$

The outcome equation:

$$RDexp_{it} = b_0 SchoolEnrol_{it} + b_1 PatAppNR_{it} + b_2 GDPPC_{it} + b_3 IPR_{it} + b_4 TO_{it} + u_{0i} \quad (7b)$$

The patent equation:

$$PatAppR_{it} = a_i Lag3RDexp_{it} + b_0 PatAppNR_{it} + b_1 GDPPC_{it} + b_2 IPR_{it} + b_3 FDI_{it} + Country\ Dummies_i + Year\ Dummies_t + u_{it} \quad (8)$$

The total factor productivity equation:

$$TFP_{it} = a_i lag1PatAppR_{it} + b_0 Lag3RDexp_{it} + b_1 PatAppNR_{it} + + b_2 FDI_{it} + b_3 IPR_{it} + b_4 TOsq_{it} + Country\ Dummies_i + Year\ Dummies_t + u_{it} \quad (9)$$

Here, a_i and $b_0 \dots\dots\dots. b_4$, the associated coefficient vectors and u_{0i} an error term, i denotes the country and t stands for the year.

4.4 Econometric Issues, Identification, and Instruments

In this thesis, we have used two frameworks i.e., Gravity model and CDM model. Both use panel data for 122 and 188 countries (developed and developing) respectively for time 2001-2019. The number of countries varies in both the panels due to data availability. While analysing the non-resident patenting, we faced a number of econometric issues that have the tendency to render biased estimates. Below we discuss some econometric issues that we come across while estimating the results. We also explain the process to identify the issues and methods to deal with.

4.4.1 Gravity Model

The study applied the closest concept suitable for an empirical analysis of patent seeking and sourcing across borders i.e., the '*gravity model*'. The concept of gravity model was first used by Timbergen (1962) and it was augmented by Anderson and Van Wincoop (2003). The gravity model has been used widely to examine trade flows (Park, 2011; Liu et al., 2016; Shin et al., 2016) where geographical distance between two countries is one of the key gravity variables. The expected sign of geographical distance in gravity model is negative which implies that higher the distance between two countries lower will be the trade volume. In the present thesis, we applied gravity model to examine the bilateral flow of patent applications between origin and destination countries. Here, we argue that patenting in other countries need not involve any physical movement of the goods at the point of filing the application. It means that an applicant files an application in any country irrespective of its distance depending upon the patenting strategy to cover different geographies. Thus, in this study we replace geographical distance with technological distance (gap) between two countries. Here, technological distance gains more relevance due to its influence on the acceptability of patent-sensitive products in the domestic market. Our model includes pair fixed effects, which control for all time-invariant differences (e.g., geographical distance between the countries) between pairs of countries. Introducing technological distance in a gravity equation to examine the bilateral flows of technology (patents) is one of the key contributions of this study.

4.4.2 Selectivity

In CDM model framework, the nature of R&D data is such that it gives rise to the problem of selectivity. Specifically, the possible selectivity bias arises from the fact that many countries do not report their R&D. We collect data from WDI and find missing data problems in case of many countries for R&D intensity variable. Since the cells are blank, considering data not reported would be more appropriate instead replacing them with zero. The value zero shows that countries have not invested in R&D in that particular year. Therefore, when a country does not report R&D expenditure, it is not clear if it does not spend anything on R&D or chooses not to report what it does because it is below a certain threshold or not captured formally.

To model the R&D investment behaviour of the countries, we rely on Heckman's two step model (1974, 1976, and 1979) to account for the problem of selection bias. Selectivity problems or selection bias is peculiar to the nature of innovation (R&D) data. Heckman's two step model consists of two equations the selection equation and an outcome equation. Where selection equation depicts whether, a country engages in research activities and outcome equation accounts for the magnitude or intensity of research investment at the country level. Specifically, the former describes the relationship between a binary participation decision (e.g., the decision to invest in R&D) and a set of covariates. While the latter describes the correlation between the outcome of interest (R&D intensity here) and a vector of the covariates. The R&D intensity is zero when a country decides not to do any formal investment in R&D, and it takes a positive value when it decides to invest in R&D. The problem of selection bias arises when we estimate the model considering only observable R&D countries and avoiding ones which for some reason don't report their R&D expenses data. In this case, applying ordinary least squares (OLS) will lead to biased estimates (Heckman, 1979). The two-step estimation strategy of Heckman takes care of the selection bias. It estimates the selection equation parameters using the probit model (with R&D dummy as dependent variable) by maximum likelihood method. The estimation gives inverse Mill's ratio (Lambda) from the selection equation. The second step involves adding the inverse Mill's ratio to the outcome equation (i.e., R&D intensity equation) to obtain estimates free of selectivity bias. The negative and highly significant coefficient for mills lambda is in the selection equation implies the presence of selection bias. Hence, restricting the estimation sample to countries with R&D expenditures values will lead to an upward bias in the estimated effect of foreign presence on domestic R&D. Dealing with selectivity problem by using Heckman's two step model on macro data is a significant contribution of this study in existing literature.

4.4.3 Simultaneity

Here, the CDM model also deals with the simultaneity issue. The simultaneity issue in the CDM model arises in our study because there is a potential bidirectional relationship between R&D investments and country's productivity. In other words, it is possible that countries that are already more productive may have a greater capacity to invest in

R&D, and R&D investments can, in turn, lead to productivity improvements. To address this issue, researchers typically use panel data, instrumental variable techniques, or a system of equations approach. In this study, we use panel data and system of equations approach to deal with simultaneity. This approach involves estimating multiple equations simultaneously, for R&D decision, R&D investment, innovation output and for productivity, and then imposing restrictions on the relationships among the four equations. We used different estimation techniques according to dependent variables of each equation. Additionally, we use lag of simultaneous variable in the following equation. For example, we use lag three of R&D expenditure in patent equation since R&D expenditure takes few years to develop the patented technology.

Annexure 1

Table 4. 4: Determinants of R&D			
Variable Category	**Proxy**	**Expected Sign**	**Empirical Findings#**
Lagged R&D intensity	Log of R&D intensity Log of business-funded and performed R&D Lag R&D	+ + +	+ and high degree of persistence: Lederman and Maloney (2003) 0 or low degree of persistence: Guellec and Pottelsberghe (2003) + Azman-Saini et al. (2018)
Direct R&D subsidies	Government funded BERD, % GDP Government funded BERD, % total BERD	Ambiguous Ambiguous	+ (long term elasticity 0.08 and marginal effect 0.70) Guellec and Pottelsberghe (2003) 0 Bassanini and Ernst (2002)
R&D tax incentives	R&D user costs of capital B-index	- -	- Bloom et al. 2002. - Guellec and Pottelsberghe (2003),
Public sector R&D	HERD, % GDP GOVERD, % GDP	Ambiguous Ambiguous	0 Guellec and Pottelsberghe (2003), - Guellec and Pottelsberghe (2003),
Specialisation in high tech industries	High-tech export share	Ambiguous	0 Almeida and Teixeira (2007)
GDP	Real GDP in constant ppp Real GDP growth rate GDP per capita in constant ppp GDP per capita growth rate	+ + +	+ Guellec and Pottelsberghe (2003), 0 Bebczuk (2002), 0 Lederman and Maloney (2003), 0 Kanwar and Evanson (2003), + Lederman and Maloney (2003) + Azman-Saini et al. (2018)
Policy	Ginarte-Park index of patent rights Kaufmann *et al.* Rule of Law Index Protection of Property right index (Fraser Institute)	Ambiguous + Ambiguous +	+ Varsakelis (2001), + Lederman and Maloney (2003), + Kanwar and Evanson (2003), + Bassanini and Ernst (2002), + Bebczuk (2002)

			+ Azman-Saini et al. (2018)
Human capital	Average years of schooling in population over 15 years Total literacy rate in population over 15 Tertiary school enrolment Share of university graduates Human Development Index	+ + + +	0 Kanwar and Evanson (2003) + Kanwar and Evanson (2003) 0 Bebczuk (2002) + Azman-Saini et al. (2018)
Openness	Exports and imports as percentage of GDP	+/0	- Bebczuk (2002)
Investment	Investment ratio Gross fixed capital formation to GDP	+ +	- Bebczuk (2002) +/0 Azman-Saini et al. (2018)
FDI	FDI (in % of the GDP) FDI inflows to GDP	+ +	0 Almeida and Teixeira (2007) - Azman-Saini et al. (2018)
Scientific Researcher	Total researchers to total employment	+	+ Azman-Saini et al. (2018)
Import	Total import of machinery and equipment to GDP	+	+ Azman-Saini et al. (2018)
Firm size	Employment share of large firms	+	+ Bassanini and Ernst (2002)
Collaboration	Index of collaboration between enterprises and universities	+	+ Lederman and Maloney (2003)
Quality of research institutions	Index of quality of academic research institutions OECD Indicator	+ -	+ Lederman and Maloney (2003) + Bassanini and Ernst (2002)
Private sector R&D	R&D performed by Firms (%)	+	+ Almeida and Teixeira (2007)
Patents	Patents (per million inhabitants)	+ +	+ Almeida and Teixeira (2007) + Thumm (2013)

Notes: #The last column summarises significant signs of the R&D determinants in existing studies. Significant signs are identified by a plus or a minus, and a zero indicates an insignificant coefficient.

Table 4. 5: Determinants of Resident Patenting			
Variable Category	**Proxy**	**Expected Sign**	**Empirical Findings#**
R&D	R&D (in % of the GDP)	+	+ Almeida and Teixeira (2007) + Qureshi et al. (2020)
	R&D performed by Firms (%)	+	0 Almeida and Teixeira (2007)
Investment	FDI (in % of the GDP)	+	- Almeida and Teixeira (2007)
Trade	High-Tech Exports (%)	+	0 Almeida and Teixeira (2007)
Human Capital	Secondary school enrolment	+	+ Qureshi et al. (2020)
Openness	Trade Openness	+	0 Qureshi et al. (2020) + MacGarvie (2005)
Imports	Import of manufactured goods	+	0 Qureshi et al. (2020)
Policy	IPR	+ +	+ Jaumotte and Pain (2005)
	Stock market size (relative to GDP)	-	+ Jaumotte and Pain (2005)
	Product and labour market regulations	-	- Jaumotte and Pain (2005)
	Foreign investment restrictions	-	- Jaumotte and Pain (2005)
	Employment protection legislation	-	-Jaumotte and Pain (2005)
	FDI restrictions into the domestic market	-	-Jaumotte and Pain (2005)
	Foreign stock	+	- Jaumotte and Pain (2005) + MacGarvie (2005) + Jaumotte and Pain (2005)

Notes: #The last column summarises significant signs of the Resident Patenting determinants in existing studies. Significant signs are identified by a plus or a minus, and a zero indicates an insignificant coefficient.

Table 4. 6: Determinants of TFP			
Variable Category	**Proxy**	**Expected Sign**	**Empirical Findings#**
Dynamic	Lagged total factor productivity	+	+ Bravo and Ortega (2011)
Openness variables	Trade (share of GDP)	+	0 Bravo and Ortega (2011)
	Trade openness	+	- Mahmood and Afza (2008)
	Trade	+	0 Zachariadis (2004)
	Imports	+	- Mayer (2001) +Xu and Chiang (2005)
	Foreign direct investment (Share of GDP)	+	0 Bravo and Ortega (2011)
	Gross foreign direct investment	+	0 Mahmood and Afza (2008)
	FDI	+	0 Zachariadis (2004)
Cyclical variables	Terms of trade	+	+ Bravo and Ortega (2011)
Human Capital	Gross secondary enrollment ratio,	+	+ Mahmood and Afza (2008)
	Secondary school enrolment	+	+ Zachariadis (2004)
Innovation Output	Number of technical and scientific journals published	+	0 Mahmood and Afza (2008)
	Patent applications	+	+Josheski and Koteski (2011) +Saini and Jain (2011) + Guo and Wang (2013)
	Foreign resident patent applications	+	+ Kim et al. (2009) + Xu and Chiang (2005)
Innovation Input	R&D investment R & D expenditure as a fraction of GDP	+	+Griliches & Mairesse (1984) +Wakelin (2001) +Wang &Tsai (2003) + Zachariadis (2004)
Policy	IPR	+	+Maskus and McDaniel (1999)

Notes: #The last column summarises significant signs of the TFP determinants in existing studies. Significant signs are identified by a plus or a minus, and a zero indicates an insignificant coefficient.

Chapter 5

Determinants of Foreign Patenting

5.0 Introduction

The previous chapter is about the conceptual framework of the thesis along with variable discussion, data sources and estimation techniques. It explained the drivers that influence foreign patenting undertaken by host countries along with the variables used for empirical estimation in the present study with literature support. Further, it presents sources of the data and detailed discussion about the estimation techniques used for the empirical investigation. The present chapter discusses the findings in terms of factors driving the foreign patenting from patent originating countries to patent recipient countries. As per the hypotheses 1 and 2 in the previous chapter, the key variables of interest are technological capabilities (proxied by technology index) and technological gap (calculated using technology index values). Our analysis includes 122 developed and developing countries with study period 2001 to 2019.

Rest of the chapter is organised as follows: Section 5.1 discusses the descriptive statistics, correlation metrics of dependent and independent variables followed by empirical results. Section 5.2 presents the detailed discussion of the results. Section 5.3 offers the concluding remarks.

5.1 Empirical Results

Our analysis includes 122 developed and developing countries with a study period 2001 to 2019. These 122 countries comprise high income (HI hereafter) and middle income (MI hereafter) countries. Here, we have specified HI and MI countries based on world bank classification. We begin by presenting descriptive statistics in Table 5. In our sample, the highest number of non-resident patent applications i.e., 88686 are filed by Japan in the US in the year 2012. While there are almost all the countries either host or home holding a minimum number of foreign patents i.e., one in different years. It includes all 122 countries as home and 109 countries as host (patent recipient) countries. Out of 109 countries 52 are HI countries and the rest 57 are MI countries. The average TI values from 2001 to 2019 indicate that all top 10 countries are high income countries with average TI of 0.49, while bottom 25 are low-income countries with average TI of 0.01. South Korea holds average highest value of TI (0.72) from 2001 to 2019. The values of the Index of patent rights lies between 1 to 5. The countries with highest and lowest values of IPR are Australia (2015-2019) Angola (2001-2004) respectively. The minimum and maximum values of gravity variables are binary and depend upon country pairs. Table 5.2 presents correlation metrics for the dependent and explanatory variables. The result does not show any potential collinearity among variables.

Table 5.1: Descriptive Statistics

Variable Name	Mean	Std. Dev.	Min	Max
$FORPAT_{ijt}$	646.5	3583.9	1	88686
TI_{it}	0.5	0.24	0	1
$LnGDPPC_{it}$	10.06	0.96	6.28	11.88
$LnGDPPC_{jt}$	10.11	0.91	6.67	11.42
IPR_{jt}	4.15	0.54	1.08	5
$TechGapTI_{ijt}$	0.35	0.21	0	1
$Contig_{ij}$	0.05	0.22	0	1
$ComnLang_{ijt}$	0.12	0.32	0	1
$ColTies_{ijt}$	0.016	0.12	0	1
$EPOHH_{ijt}$	0.27	0.44	0	1
$IPR_{jt}TI_{it}$	2.05	1.05	0	4.88

First, we present results of the estimation based on all countries sample and then by subgroups of HI and MI countries. Since our dependent variable shows the bilateral flows of patenting between country pairs, we classify the dataset in seven categories (1) bilateral patent flows among all country pairs, (2) HI countries to all countries, (3) middle MI countries to all countries, (4) MI to HI, (5) HI to MI, (6) HI to HI, (7) MI to MI. We applied negative binomial regression technique, as our dependent variable is count data. To choose between fixed effect and random effect model, we used Hausman test statistics (Hausman 1978). The null hypothesis of the Hausman test is that there is no systematic difference in fixed and random coefficients (Greene 2008). The result of the Hausman test (p-value is 0.00) rejects the null hypothesis (i.e., random effect model is appropriate) and accepts the alternative hypothesis (i.e., fixed effect model is appropriate).

With the gravity model framework, we capture the effects of specific variable i.e., technological gap along with other gravity variables (contiguity, common language, and colonial ties) on bilateral patenting between different country pairs. We focus on technological gap (technological distance) as patenting in other countries need not involve any physical movement of the goods at the point of filing the application. A patentee files an application in any country irrespective of its distance depending upon the patenting strategy to cover different geographies. Here, technological distance (gap) gains more relevance due to its influence on the acceptability of patent-sensitive products in the domestic market. However, pair fixed effects absorb all time-invariant variation that is specific to each pair, which would typically include distance. Since pair fixed effects are already included in the model, the distance between the countries is already controlled for. We first include only key variables of interest and later include control variables. We have performed time fixed effects and country pair fixed effects tests in all the specifications to check year specific and country pair specific effects. We presented the results variable wise. Variable wise interpretation of results facilitates comparison of same indicator in different country groups. It gives more clarity and understating to a reader.

Table 5.2: Matrix of Correlations											
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) ForeignPat	1.000										
(2) TIHome	0.044	1.000									
(3) TechDistTIHost	-0.044	-0.962	1.000								
(4) LnGDPPCHost	0.039	0.025	-0.022	1.000							
(5) LnGDPPCHome	0.062	0.243	-0.243	0.001	1.000						
(6) Contig	0.015	0.030	-0.030	0.008	0.001	1.000					
(7) ComnLang	0.021	-0.067	0.067	-0.030	-0.003	0.145	1.000				
(8) ColTies	0.022	0.030	-0.030	0.056	0.035	0.071	0.176	1.000			
(9) IPRHost	0.055	0.047	-0.042	0.733	0.012	0.023	-0.019	0.062	1.000		
(10) IPRTI	0.047	0.579	-0.549	0.385	0.065	0.014	0.009	0.043	0.535	1.000	
(11) EPOHH	-0.015	0.152	-0.154	0.277	0.234	0.136	-0.089	0.026	0.247	0.144	1.000

5.1.1 Results of Foreign Patenting Equation

Table 5.3 reports the empirical results based on negative binomial model with FE estimations. The result shows that the coefficient of technology index of home (TIHome) is positive and statistically significant in two cases, namely all countries (full sample, All hereafter) and HI to All countries. It indicates that countries with high technological capabilities (TCs) do higher patenting in foreign countries. But it shows negative relationship in case of MI to All countries. It shows that excluding TCs there are several other factors that affects patenting activities of middle-income countries such as GDP per capita, patent filing cost, IP awareness, lucrative market in patent recipient country, IPR system of patent recipient country etc. The combination of such factors may give positive results. Our other variable of interest is TechGapTIHost which is negative and significant in all cases except HI to All countries. Therefore, it highlights those countries with higher technological gap manifest lower cross-country patenting. However, in case of HI to All countries it is insignificant as HI countries are technologically advance and TechGap from frontier country is relatively lesser.

This outcome suggests that the concept of a technology gap operates in a manner similar to the physical distance factor considered in international trade theory. In international trade, bilateral trade tends to decrease as the distance between source and destination countries increases, even though technology trade doesn't involve the physical movement of goods. However, there is a distinction between the two scenarios when it comes to measuring the concept of distance or gap. In technology trade, the "technology gap" refers to the disparity between the destination country and the technology frontier country within a specific year, as opposed to the measurement of distance between the source and destination countries as typically done in international trade. In earlier research by Eaton and Kortum (1996), they observed that foreign patenting tends to be more substantial when the distance between two countries is smaller, the destination country exhibits a greater capacity to assimilate technology (as indicated by the level of human capital), and the destination country enjoys a higher level of relative productivity. Comparable factors are also connected with technology flows.

Further, LnGDPPCHost has a positive and significant impact on foreign patenting across all three cases. It indicates that countries with higher GDP per capita receive higher number of patent applications from other countries. A higher GDP per capita represents more developed economies. These economies have wide and competitive markets and provide stronger IP protection that attracts more patent applications from all over the world. However, developing economies with relatively low GDP per capita are unable to attract that many patent applications.

The LnGDPPCHome is positively significant across all cases implying that countries with higher GDP per capita tend to file more patents abroad. This may be due to the fact that developing economies, which have lower GDP per capita, generally allocate less funds towards R&D, resulting in lower levels of innovation and patenting, both domestically and internationally. In contrast, developed economies with higher GDP per capita typically invest a larger proportion of their GDP in R&D, resulting in higher innovative capacity and greater patenting activity, both at home and abroad. As developing countries' firms are technologically laggards and not able to compete with the highly innovative firms in the developed country market, they have less incentive to file patents in highly competitive countries. On the other hand, the developed country firms are highly competitive, innovative, and efficient to exploit developing country markets. As a result, the share of patenting activity of developed countries is high in the developing countries.

Further, our result shows that the coefficient of index of PRs is positive and statistically significant for two cases i.e., All to All countries and HI to All countries models. The coefficient estimate indicates that strong IP protection stimulates inflow of foreign patent applications in the host country. However, it is negative and significant in case of MI to All countries. It shows that MI countries are less likely to patent in countries with stronger IP protection. Such a result indicates that holding technology index constant for all MI countries, a higher level of host country's PRs is associated with a lower volume of such country's patenting outflow. As patents from MI countries may not be able to meet the patentability criterion of other countries and any increase in that case of IP protection will negatively influence patent flow from MI to All countries.

It means that though MI economies have been undertaking R&D initiatives and gaining foregrounds in technological breakthrough, yet these countries are not at the frontier of many technological areas.

Following Shin et al. (2016), this study has controlled for an interaction effect, to capture the combined effects of the technological capabilities of a source country and the patent rights (PRs) of the destination countries on the cross-country patenting of the source countries. We find that the interaction coefficient is positively related to foreign patenting in the case of all three country groups and is highly significant for all the groups. Such a result indicates that holding IP strength constant, a higher level of host country's TI is associated with a higher volume of home country's patenting outflow. In other words, the effect of patent receiving country's IP protection on a patent source country's patent filing is highly dependent on the source country's technological capabilities.

Table 5.3: Results of Foreign Patenting Equation			
Dependent Variable ForeignPat	NB_FE All_to_All	NB_FE HI_to_All	NB_FE MI_to_All
TIHome	0.249***	0.345***	-0.311***
	(5.18)	(6.25)	(-3.47)
TechDistTIHost	-0.125***	-0.0538	-0.437***
	(-2.61)	(-0.98)	(-4.72)
LnGDPPCHost	0.0474***	0.0538***	0.0438*
	(4.72)	(4.68)	(1.93)
LnGDPPCHome	0.177***	0.175***	0.752***
	(19.65)	(9.55)	(26.41)
Contig	0.483***	0.498***	0.222***
	(11.85)	(10.15)	(2.67)
ComnLang	0.205***	0.163***	0.396***
	(7.84)	(5.31)	(6.75)
ColTies	0.0328	0.0515	0.109
	(0.59)	(0.85)	(0.62)
IPRHost	0.121***	0.149***	-0.0487*
	(9.32)	(10.11)	(-1.75)
IPRTI	0.0917***	0.0608***	0.183***
	(13.61)	(7.76)	(14.19)
EPOHH	-1.143***	-1.126***	0.00864
	(-42.90)	(-40.23)	(0.03)
Year fixed effects	Yes	Yes	Yes
Pair fixed effects	Yes	Yes	Yes
Prob > chi 2	0.0000	0.0000	0.0000
_cons	-1.668***	-1.862***	-5.359***
	(-13.06)	(-8.66)	(-17.88)
N	39469	28417	11052

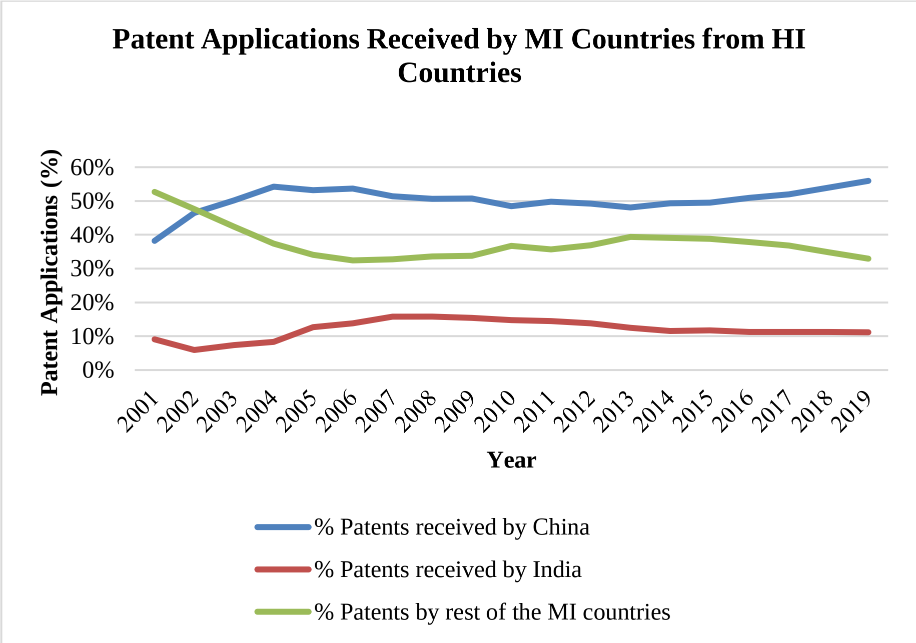
Notes: t statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

The coefficient of gravity variables contiguity and common language are positive and significant in case of all country groups which implies that countries with common geographical borders and common languages do significant bilateral patenting. Both gravity variables support the gravity model hypothesis. However, the coefficient for the third gravity variable, colonial ties, is insignificant in all three cases. It implies that there is no impact of past colonial ties of the countries on their cross-country patenting activities. The last variable EPOHH is negative and significant in the case of All to All and HI to All country groups. It implies that if home and host country both operate in EPO, the bilateral patenting reported is on an average lower than the non-European pairs. The coefficient of EPOHH is insignificant in case of MI to All country groups.

Our group wise analysis (see Table 5.4) shows that the coefficient of technology index of home (TIHome) is positive and statistically significant for the country groups HI to HI. This result indicates that countries technological capabilities positively stimulate cross-countries patenting. However, we find that the coefficient of technology index is negative and significant for MI to MI country group. A possible reason for this result is that MI countries with higher technological capabilities would be more interested in filing patents in HI countries rather in other MI countries due to larger market. Technological index coefficient is insignificant for HI to MI and MI to HI case, highlighting the fact that patentees from HI countries do not consider the technological abilities of the host countries. This counterintuitive result can be explained once we look at the granular data where we find that HI countries' patent application is higher in China compared to other MI countries. In 2019, China's share was 56 percent of total patent application filed by HI countries in MI countries (refer Figure 5.1). Thus, it is Chinese market that is of interest for patentees based in HI economies leading the TI coefficient to be insignificant. Further developing countries' innovation is based on adaptive technology, hence they are not applying many patents in HI countries.

Our other variable of interest is TechGapTIHost that is negatively significant in all cases except HI to HI countries. It implies that countries with lesser technological gap from frontier country receives higher patent applications. However, there is not much difference in terms of technology between two HI countries therefore coefficient of TechGapTIHost in HI to HI case is insignificant. In this particular scenario, patenting behavior appears to be influenced by a multitude of factors, largely associated with the characteristics of the destination country's market. These factors may encompass market size, the potential attractiveness of the market for specific technologies or products, competition dynamics, and more. Further, the coefficients of LnGDPPCHost and LnGDPPCHome are positive and significant in all the cases and hold the same explanation as above Table 5.3.

Figure 5.1: Patent Applications Received by MI Countries from HI Countries



The result shows that the coefficient of index of PRs is positive and statistically significant for only MI to MI countries. The possible reason could be the less variation of the strength of PRs protection in MI countries. We have found that for many MI countries PRs have not been changed across the time (2005, 2010, 2015), for example, in case of India, Philippines, Tunisia, Mauritius, Nigeria the strength of PRs protection is similar in 2005, 2010, and in 2015, i.e., 3.76, 3.88, 3.38, 2.57, 2.89 respectively. The standard deviation of index of PRs is 0.21 for all MI countries.

While in the case of HI to MI and MI to HI countries the coefficient of index of PRs is negative and significant. It indicates that countries with stronger PRs receive relatively lesser patent applications from MI countries. In case of MI country (with relatively weak PRs) very few countries such as China and India receive patent applications particularly from HI countries. The coefficient estimate indicates that strong PRs protection stimulates inflow of foreign patent applications in the host country mostly from HI countries.

Further, we find that interaction coefficient of IPRHost and TIHome is positive and significant across all cases. For HI to HI and MI to case, our positively significant IPRTI coefficient shows that with same level of IPR an increase in

TI of home will increase the inflow of patents from another HI/MI country. In case of interaction coefficient of MI to HI group, there is very less variation in IPR of HI, the explanation based on constant IPR and varying TI would be relevant. Accordingly, the positive coefficient shows an increase in the TI will increase patent flow from MI to HI significantly. While in the second case, HI to MI, the positively significant interaction effect implies that as the technology level of HI countries is almost similar, therefore keeping TI constant, stronger patent rights in MI countries leads to more patent inflows from HI countries.

Further, the coefficient of gravity variable contiguity is positive and significant for HI to HI. The coefficient of common language is positively significant in all cases. It implies that the common official language of host and home countries is also a contributing factor for international patenting. Since patent filing is sensitive to patenting cost, sometimes higher translation fees discourage patentee to file a patent application in other country. Thus, host country sharing an official language with patent originating country is more likely to receive patent applications than other countries. Lastly, for variable past colonial ties, it is positively significant in case of HI to HI countries. The coefficient of EPOHH is negative and significant in the case of HI to HI countries which implies that if home and host country both operate in EPO, the bilateral patenting reported is on an average lower than the non-European pairs. It indicates that the host countries are probably not preferable markets for the patent filing countries. Thus, in the case of HI to HI countries, host and home countries being a member states of EPO does not drive bilateral patenting flow.

Table 5.4: Results of Foreign Patenting Equation				
Dependent Variable ForeignPat	NB_FE HI to MI	NB_FE MI to HI	NB_FE HI to HI	NB_FE MI to MI
TIHome	-0.203	-0.203	0.259^{***}	-0.421^{***}
	(-1.62)	(-1.62)	(3.33)	(-3.42)
TechDistTIHost	-0.216^{*}	-0.216^{*}	0.00486	-0.780^{***}
	(-1.70)	(-1.70)	(0.06)	(-5.94)
LnGDPPCHost	0.389^{***}	0.389^{***}	0.478^{***}	0.303^{***}
	(6.76)	(6.76)	(20.44)	(7.46)
LnGDPPCHome	0.823^{***}	0.823^{***}	0.0987^{***}	0.470^{***}
	(21.20)	(21.20)	(4.24)	(10.51)
Contig	0.105	0.105	0.345^{***}	0.119
	(0.60)	(0.60)	(6.32)	(1.25)
ComnLang	0.409^{***}	0.409^{***}	0.204^{***}	0.495^{***}
	(5.48)	(5.48)	(5.37)	(4.87)
ColTies	0.228	0.228	0.133^{*}	0.213
	(1.25)	(1.25)	(1.76)	(0.14)
IPRHost	-0.237^{***}	-0.237^{***}	-0.00871	0.0676^{*}
	(-4.83)	(-4.83)	(-0.36)	(1.87)
IPRTI	0.170^{***}	0.170^{***}	0.0629^{***}	0.154^{***}
	(10.44)	(10.44)	(6.30)	(7.11)
EPOHH	0.116	0.116	-0.706^{***}	11.84
	(0.42)	(0.42)	(-21.44)	(0.02)
Year fixed effects	Yes	Yes	Yes	Yes
Pair fixed effects	Yes	Yes	Yes	Yes
Prob > chi 2	0.0000	0.0000	0.0000	0.0000
_cons	-8.982^{***}	-8.982^{***}	-5.018^{***}	-5.089^{***}
	(-14.66)	(-14.66)	(-14.91)	(-11.16)
N	6046	6046	16180	5006

Notes: *t* statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

5.2 Discussions

This research discusses the contributing factors to inward foreign patenting in host countries. It is hypothesised that technological capabilities of home countries influence their outward foreign patenting in the host countries that further stimulates the technology trade. We have empirically shown that a home country's technological capabilities positively stimulate foreign patenting flow in case of All to All, HI to All, HI to HI countries. This result is consistent with previous studies (Bruche, 2009; Jin et al., 2014) as factors like large markets and skilled and inexpensive human resources of MI or developing countries attracts developed countries firms for patenting. Additionally, stronger PRs and competitive markets attract HI countries to file patents in HI countries. In the case of HI countries (host and home both), other factors such as lucrative market and export competition etc. influence the foreign patent application inflow. Furthermore, the technological capabilities of home country negatively influence the foreign patenting in case of MI to All and MI to MI countries. This result might be driven by the case of China where China’s technological capabilities are relatively higher than other MI countries, but China’s domestic patenting is much higher than outbound foreign patenting.

The technological gap of host country is negative and significant in case of all countries except HI to All (insignificant) and HI to HI (insignificant), which supports our hypothesis. In the trade literature, physical distance between two countries plays a crucial role in determining the foreign trade of merchandise goods (Eaton & Kortum, 1996; McCalman, 2001; Smith, 1999; Rafiquzzaman, 2002), however, in the technology trade (inflow or outflow of patent applications) it may or may not be negative and significant. Since patenting in other countries does not involve any physical movement of things, a patentee file patent in any country of the world irrespective of its distance. Our results indicate that the gap in terms of technological capabilities between two countries serves as a pivotal determinant of technology trade. In essence, this suggests that even though technology trade doesn't rely on physical proximity, the level of technological advancement in both the source and destination countries significantly impacts the flow of technology. Past theoretical studies also explained that technological laggard countries may face a disadvantage of backwardness because of their limited absorptive capacity, and thus the existing technology gap may impede learning in the international technology diffusion (Aghion et al., 2005; Castellacci, 2011; Popp, 2006).

Chapter 6

Impact of Foreign Patenting on Host Country

6.0 Introduction

The previous chapter presented data details and results regarding drivers of foreign patenting in host and home countries. We find that technological capabilities of home countries incentivise lead to patenting of the outcome of R&D investment in host countries. An emerging country devises policies to attract foreign firms as those are expected to be a significant contributor to the host country's innovation system and patenting activities. Such policy changes include designing patent policies as per the international standards. Thus, it is very important for a host country to understand the impact of foreign patents on domestic innovation and productivity. We present the results of empirical exercise conducted to find the influence of foreign patenting on host country's domestic R&D, resident patenting, and total factor productivity in this chapter.

Rest of the chapter is organised as follows: Section 6.1 discusses the descriptive statistics, correlation metrics of dependent and independent variables. It also presents the empirical results of R&D, Patent and TFP equations. Section 6.2 presents the detailed discussion of the results. Section 6.3 offers the concluding remarks.

6.1 Empirical Results

This section provides a detailed discussion of the empirical results of innovation input, innovation output and total factor productivity equations. For discussion we follow the same pattern for all three equations. First, we discuss the results of key variables of interest and then controls. Also, first we discuss the results of full sample (All hereafter) of countries and then sub samples i.e., high income (HI hereafter), upper-middle income (UMI hereafter), lower-middle income (LMI hereafter) and low income (LI hereafter) to see the varying effect of each variable in different country groups.

6.1.1 Results of Innovation Input (R&D) Equation

This section provides the interpretation of results aligned with the equation (1a) and (1b) of Chapter 4. We begin with descriptive statistics presented in Table 6.1. In our sample of 188 countries, the US is the highest foreign patent receiving country. The highest number of patent applications received by the US is 313052 in 2017. The minimum value is 1, which is received by many countries in different years. Country that invested highest in R&D is Israel (4.95 percent of its GDP) in 2018. Country with lowest R&D investment is Zambia (only 0.005 percentage of GDP) in 2002. Country with highest resident patents is China in 2018 and lowest resident patents filed by many countries in different years. Kuwait (due to oil producing country) holds highest productivity value in year 2005 and Tajikistan holds lowest TFP in 2001. Table 6.2 presents correlation metrics for the dependent and explanatory variables. The result does not show any potential collinearity among variables.

Table 6.1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
RDexp	1635	.937	.964	.005	4.953
PatAppRes	2953	13499.052	79946.89	1	1500000
TFP	2223	.983	.154	.283	2.108
PatAppNR	1954	6266.479	26268.292	1	313052
SchoolEnrol	2453	81.271	28.811	6.487	163.935
GDPPC	3465	15203.545	22604.547	194.873	196061
IPR	2204	3.284	.909	.2	5
TO	3266	92.254	60.447	.167	860.8
FDI	3330	7.953	52.374	-1268.17	1282.63

Table 6.3 shows the results of the innovation input equation using Heckman's two step model. The Heckman two-step model is commonly used to correct sample selection bias in econometric analysis. The Inverse of the Mills' Ratio (IMR), which is also known as the selection correction term, is a key component of the Heckman model.

In our results, the coefficient of IMR for All countries is negative and significant. It indicates that the selection process is negatively related to the outcome equation. A negative coefficient on the IMR suggests that the selection bias is negative, which means that the excluded individuals have a higher probability of experiencing the outcome of interest. It implies that, conditional on the observed values of the independent variables, a higher probability of being selected for the sample is associated with a lower level of the outcome variable. In our model the R&D expenditure is the outcome variable, and the foreign patent applications are the key independent variable of interest. The R&D dummy variable is the dependent variable in the selection equation, and school enrolment is used as an exclusion restriction variable.

The key intuition we had was that given the sequential nature of developmental progress, nations undergo distinct transitions as they move from one stage of development to another. This is particularly evident as countries transition from agrarian economies to industrialized ones. In this context, the metric of manufacturing exports (MES) serves as an indicator of a developmental stage wherein a nation has successfully traversed the agricultural phase and entered the realm of industrialization. While we initially employed MES as an exclusion restriction variable, our analysis revealed that the coefficient associated with manufacturing exports lacks statistical significance across all country groupings within the selection equation.

We have also considered an exclusion restriction variable that represents some minimum development level. We collected data for the variable "Poverty gap at $2.15 a day (2017 PPP) (%)" from the World Bank WDI database. The poverty gap at $2.15 a day (2017 PPP) is the mean shortfall in income or consumption from the poverty line $2.15 a day (counting the nonpoor as having zero shortfall), expressed as a percentage of the poverty line. This measure reflects the depth of poverty as well as its incidence. Our results indicate that the coefficient of poverty level (exclusion restriction variable) is not significant in the case of R&D decisions in any of the country groups. Further, we included secondary school enrolment as one of the explanatory variables of R&D in the outcome equation. The result shows that the coefficient of secondary school enrolment is also insignificant in all the groups

We also attempted the model with trade openness and index of intellectual property rights as exclusion variables (separately). However, in view of the lack of theoretical base along with statistical insignificance of these variables in the models, we decided to drop them. Finally, we reported the results using secondary school enrollment as an exclusion restriction variable.

Here, the coefficient of IMR shows that the sample is biased towards countries with lower R&D expenditure levels. However, the use of the exclusion restriction variable (school enrolment) helps to mitigate this selection bias by addressing the endogeneity problem that may exist between the R&D expenditure, the selection equation, and the foreign patent applications.

The results of selection equation and outcome equation shows that the coefficient of non-resident patent applications variable is positive and significant for All countries. It indicates that non-resident patent applications positively influence both the country's R&D decision as well as R&D investment. It means a higher number of foreign patent applications encourages domestic R&D activities. In sub samples, the coefficient of non-resident patent applications is positive and significant in case of UMI, LMI and LI countries. However, it is insignificant in the case of HI countries. The insignificant coefficient shows that foreign patent applications does not influence the decision of HI countries to invest in domestic R&D since they are already investing significantly in R&D activities. The possible explanation of such a result is that HI countries already have a high level of technological capabilities, hence any additional contribution is not significant.

Table 6.2: Matrix of Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) RDexp	1.000								
(2) PatAppRes	0.377	1.000							
(3) TFP	-0.038	-0.034	1.000						
(4) PatAppNR	0.240	0.940	-0.042	1.000					
(5) SchoolEnrol	0.494	0.021	0.095	-0.049	1.000				
(6) GDPPC	0.611	0.185	0.136	0.125	0.544	1.000			
(7) IPR	0.588	0.306	0.038	0.228	0.608	0.584	1.000		
(8) TO	-0.009	-0.171	-0.107	-0.158	0.115	0.321	0.056	1.000	
(9) FDI	-0.086	-0.054	-0.051	-0.047	0.027	0.059	-0.041	0.309	1.000

The coefficient of school enrolment in selection equation is positive and significant for All countries which implies that country's decision to invest in R&D depends upon it. However, the results of sub samples show varying effect of school enrolment variable. It is negatively significant in the case of LI countries. It indicates that possibly due to limited resources in LI countries, increase in school enrolment will shift the government expenditure decision to education instead contributing to R&D investment decision.

Our findings reveal that in both All countries and LI countries, the coefficient of the exclusion restriction variable is statistically significant in the selection equation. This suggests that there is no evidence of selection bias affecting the results. However, in the remaining three groups (HI, LMI, and UMI), the coefficient of the exclusion restriction variable is statistically insignificant in the selection equation, implying the potential presence of bias in these cases. Interestingly, among these three models, our primary variable of interest, PatAppNR, is statistically significant in the outcome equation for UMI countries.

According to Cameron and Trivedi (2010) it is often hard to come up with an excluded variable that does not directly affect the outcome and does affect the selection. Thus, we required a variable as an exclusion restriction that may or may not affect the outcome variable indirectly. This means it may be sensitive to other explanatory variables. We encounter a comparable situation where the selection of a suitable exclusion restriction variable aligns with the criteria outlined by Cameron and Trivedi.

To strengthen the reliability of our conclusions, we conducted additional analyses using the Heckman selection model, following the methodology outlined in Cameron and Trivedi (2010). This comprehensive approach involved three stages:

First, we applied the Heckman model with the maximum likelihood estimator, without employing any exclusion restriction.

Second, we implemented the Heckman model in a two-step process, again without the use of an exclusion restriction.

Third, we utilized the Heckman model with the maximum likelihood estimator, but this time we incorporated an exclusion restriction.

Our results pertaining to the exclusion restriction variable largely align with our initial findings in terms of their statistical significance, with one notable exception in the case of LMI countries. Within the LMI group, the coefficient associated with the exclusion restriction variable (SchoolEnrol) demonstrates statistical significance in the Heckman model with the maximum likelihood estimator and exclusion restriction. This outcome suggests that there is no evidence of selection bias affecting the results for LMI countries. The results concerning our primary variable of interest, PatAppNR, remains unaltered even in this model.

Further, the coefficient of GDPPC is insignificant in selection equation for All sample while it is positive and significant in outcome equation. It indicates that GDPPC plays an important role for R&D investment rather R&D decision. In the case of LMI countries in outcome equation, the coefficient of GDPPC is negative and significant. It shows that the increase in GDP per capita is inversely related to domestic R&D investment. In LMI countries, the existing level of technology, IPR, trade etc. is not very promising. Therefore, the focus of the country is promoting basic growth parameters such as education, employment, sanitation, health etc. instead technology advancement by promoting R&D expenditure. The technology led growth can be achieved once the growth of basic parameters is achieved by the country.

The rest of the control variables coefficients such as index of patent rights and trade openness are positive and significant in selection equation for All countries. In outcome equation coefficient of IPR is positive and significant, it implies that IPR is a contributing factor for both R&D decision and R&D investment in a country. However, trade openness influence R&D decision of a country to some extent but it negatively affect R&D investment in case of All countries. This is quite possible that this result is driven by technologically advanced countries. The large multinationals of such countries are highly involved in internalisation of their R&D activities. They set up their R&D units in emerging economies instead investing in domestic R&D to take advantage of low-cost skilled manpower, resources, and competitive markets.

Comparing the estimated coefficients of all income levels, we see that non-resident patent has a stronger positive effect on R&D expenditure for UMI countries than for other income groups. The index of patent rights has a stronger positive effect on R&D decision for HI and UMI countries than for other income groups. Trade openness has a higher impact on R&D expenditure of UMI countries than others. Finally, GDPPC has the strongest positive effect on R&D expenditure for All countries and UMI countries. These findings suggest that promoting international knowledge flows and protecting intellectual property rights can stimulate R&D expenditure across all income levels. Additionally, promoting education may have a positive impact on R&D expenditure for HI, UMI and LMI countries. Overall, these results can inform policymakers in their efforts to promote innovation in different income groups.

Studies on similar line by Castellani et al. (2017) found that foreign patenting has a positive and significant effect on the R&D investment of Italian firms. Similarly, a study by Li et al. (2017) found that foreign patenting has a positive and significant effect on the R&D expenditure of Chinese firms. However, other studies have reported mixed or inconclusive results, depending on the country context and the level of analysis. For example, a study by Mancusi and Sobrero (2014) found that foreign patenting has a positive effect on the R&D intensity of Italian firms but only for those operating in high-tech sectors. Another study by Hu and Mathews (2008) found that foreign patenting has a negative effect on the R&D expenditure of Chinese firms, but only for those that are technologically less advanced. Therefore, the relationship between non-resident patenting and innovation input can vary depending on various country-specific factors, such as the level of development, technological capabilities, institutional environment, and firm/country characteristics.

Table 6.3: Results of Innovation Input Equation (R&D Equation)

	HM_TS_All	HM_TS_HI	HM_TS_UM	HM_TS_LM	HM_TS_LI
Selection Equation (RDDummy)					
SchoolEnrol	0.00640**	0.00126	-0.0107	0.00985	-0.0667**
	(2.52)	(0.20)	(-1.61)	(1.53)	(-2.22)
PatAppNR	39.681***	4.315	203.735***	106.393***	50781.79***
	(3.69)	(0.77)	(4.43)	(2.95)	(2.79)
GDPPC	-0.00000392	-0.0000209***	0.0000533	0.000131***	-0.000424
	(-1.34)	(-4.95)	(1.19)	(3.04)	(-0.52)
IPR	0.694***	1.096***	0.841***	0.0922	0.971**
	(7.95)	(5.67)	(4.24)	(0.52)	(2.15)
TO	0.00178*	0.00489***	-0.00742***	0.00846	-0.0395***
	(1.93)	(3.36)	(-3.02)	(1.58)	(-2.61)
_cons	-2.437***	-2.895***	-1.528**	-2.079***	1.103
	(-9.84)	(-3.19)	(-2.18)	(-4.53)	(0.89)
Outcome Equation (RDexp)					
PatAppNR	2.027**	0.0730	13.547***	-0.8505	-8972.28***
	(2.37)	(0.02)	(9.73)	(-0.09)	(-2.60)
GDPPC	0.0000244***	0.0000376*	0.0000573***	-0.0000474**	0.000448**
	(14.36)	(1.71)	(7.88)	(-2.11)	(1.99)
IPR	0.180*	-0.549	0.0739	-0.1000	-0.0654
	(1.68)	(-0.45)	(1.55)	(-1.35)	(-0.66)
TO	-0.00313***	-0.00710	0.00301***	0.00215	0.00759*
	(-6.53)	(-1.54)	(5.93)	(0.86)	(1.69)
_cons	0.461	4.017	-0.357*	1.119**	0.0716
	(0.96)	(0.75)	(-1.86)	(2.30)	(0.26)
/mills					
Lambda	-0.759***	-4.157	-0.247***	-0.433*	-0.188
	(-3.13)	(-1.04)	(-2.94)	(-1.75)	(-1.32)
N	1157	587	297	219	54

Notes: *t* statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

6.1.2 Results of Innovation Output (Patent) Equation

Table 6.4 presents the results of a regression analysis that examines the determinants of innovation output, measured by residential patent applications, in different income groups. The study finds that some factors are more important for certain income groups, suggesting that policymakers should consider different policy interventions to promote innovation. Our key variable of interest, non-resident patent, has a positive and significant effect on innovation output across all income levels country groups except LI countries. This finding suggests that international knowledge flows play an important role in promoting innovation. In HI countries, non-resident patents have a spillover effect on resident patents. When non-resident patents are granted in a HI country, they stimulate innovation and generate new ideas that lead to more resident patents in that country. This could be due to increased competition, access to new technologies, and collaboration between inventors from different countries. Jaffe and Trajtenberg (2002) found that foreign patenting in the US had a positive effect on domestic innovation. The UMI countries may have more open economies and greater exposure to international competition, which creates incentives for firms to innovate to remain competitive. Non-resident patents can serve as a source of knowledge and technology transfer, which can facilitate this innovation process. In the case of LMI countries, non-resident patents can serve as a source of knowledge and technology transfer for firms. Such firms may not have the resources or capabilities to develop these innovations on their own. The granting of non-resident patents in these countries may also create incentives for local firms to innovate to compete with foreign firms. Basant (1992) examined the impact of patenting by foreign firms on innovation in Indian firms, which is a lower middle-income country, and found that foreign patenting had a positive effect on innovation by Indian firms.

Results suggest that there is no significant effect of non-resident patents on resident patents in LI countries. Such a result indicates that the innovation system in these countries is not yet sufficiently developed to absorb the knowledge and technology transfer that non-resident patents can potentially provide. Additionally, these countries may lack the necessary infrastructure, institutions, and policies to facilitate innovation and promote technology transfer. Furthermore, the effect of non-resident patent on innovation is stronger for LMI countries than for HI or UMI countries.

The next independent variable, R&D expenditure is used with a lag of three years. Since R&D expenditure is a dependent variable in the preceding equation, using it as a normal variable would create a problem of simultaneity. Therefore, we attempt to use lag one, lag two and lag three of R&D investment variable. We find that in the case of R&D expenditure and innovation output, the choice of lag structure can greatly impact the estimation results and the interpretation of the relationship between the two variables. In selecting the lag structure for R&D expenditure, it is important to consider the time frame over which the effects of R&D spending on innovation output may materialise. A lagged effect of R&D spending on innovation output means that the benefits of R&D spending may not be immediately realised. Instead, there may be a delay before the benefits of R&D spending are reflected in innovation output. A study by Hu and Mathews (2008) investigated the impact of R&D expenditure on the patent output of Chinese firms. They found that the lagged effect of R&D expenditure on patent output was significant, with a lag of two years providing the best fit for their data.

Here, lag three of R&D expenditure has a positive and significant effect on innovation output of All countries, HI and UMI countries while insignificant for LMI and LI countries. Here, lagged variable shows that R&D expenditure takes around three years to convert into a patentable invention. This finding suggests that R&D investment made three years ago tends to have a positive impact on patenting activity of HI and UMI countries. Because the benefits of R&D investment may take some time to materialise but can eventually lead to an increase in patenting activity. Additionally, the positive effect of lagged R&D expenditure on patents may reflect the cumulative nature of innovation, where new ideas and technologies build upon previous knowledge and discoveries. Mairesse and Hall (1996) found that lagged R&D investment has a positive effect on innovation in France, Germany, and the US. Our results show that the effect of R&D expenditure on innovation is stronger for UMI countries than for HI countries.

The present study finds that per capita income, as measured by GDP per capita (GDPPC), has a positive and significant effect on innovation output in all income groups except LI countries. A positive and significant effect of GDPPC on resident patents means that countries with higher GDPPC tend to produce more patents compared to countries with lower GDPPC. This finding suggests that economic prosperity and innovation are closely related. Also, it indicates that higher levels of economic development provide greater access to resources, such as education, infrastructure, and R&D funding, which are essential for innovation. This suggests that promoting overall development can stimulate innovation, which is consistent with prior research (Chaminade & Edquist, 2006; Galindo & Mendez, 2014; Gossling & Rutten, 2007).

FDI has a negative and significant effect on resident patents in All countries and HI countries. This suggests that FDI may displace domestic innovation activities, which is consistent with some prior research (Branstetter et al., 2006). This finding suggests that foreign firms may be more likely to focus on exploiting existing technologies rather than developing new ones, which may limit the incentives for domestic firms to innovate. However, the effect of FDI on innovation is not significant for UMI, LMI and LI countries. In UMI countries, it may depend on a variety of factors such as the technological capabilities of the host country, the level of intellectual property protection, and the competitiveness of the local market. Another explanation would be FDI is not specifically going to R&D activities rather other business activities of the firms. In LMI countries, due to low levels of R&D intensity and lack of absorptive capacity of local firms may hinder the potential benefits of FDI in terms of increasing patenting activity. The index of patent rights has a positive and significant effect on innovation output for All countries and for HI and UMI countries specifically. This finding suggests that having strong intellectual property rights protection can incentivise innovation activities, which is consistent with prior research.

The study finds that factors like non-resident patenting, IPR and R&D expenditure, are more important for certain income groups in promoting innovation. The findings suggest that policymakers should consider different policy interventions to promote innovation in different income groups. Specifically, increasing investment in R&D, promoting international knowledge flows, and protecting intellectual property rights can stimulate innovation activities in HI and UMI countries. For LM countries promoting international knowledge flows and GDP per capita are key driving factors of innovation.

Table 6.4: Results of Innovation Output (Patent) Equation

Dependent Variable	NB_FE_All	NB_FE_HI	NB_FE_UM	NB_FE_LM	NB_FE_LI
PatAppRes					
PatAppNR	2.44^{***}	2.64^{***}	13.59^{***}	44.801^{***}	16193.58
	(4.48)	(4.89)	(6.53)	(3.24)	(1.16)
L3RDexp	0.356^{***}	0.313^{***}	0.674^{***}	0.430	-1.188
	(12.19)	(10.64)	(3.78)	(1.41)	(-0.86)
GDPPC	0.0000107^{***}	0.00000753^{***}	0.000161^{***}	0.000194^{***}	-0.00144^{*}
	(6.13)	(3.70)	(7.22)	(4.45)	(-1.74)
FDI	-0.00136^{***}	-0.00153^{***}	0.00943	-0.0138	-0.0326
	(-2.63)	(-3.14)	(1.16)	(-0.62)	(-0.96)
IPR	0.478^{***}	0.357^{***}	0.158^{**}	0.0935	1.321
	(9.99)	(5.18)	(2.32)	(0.80)	(1.38)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Pair fixed effects	Yes	Yes	Yes	Yes	Yes
Prob > chi 2	0.0000	0.0000	0.0000	0.0000	0.0000
_cons	-0.0531	0.773^{***}	0.194	0.887^{**}	-1.495
	(-0.29)	(2.67)	(0.67)	(2.44)	(-0.69)
N	876	510	211	125	30

Notes: t statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

6.1.3 Results of Total Factor Productivity Equation

Table 6.5 shows the results of the TFP equation for All countries, HI countries, UMI countries, LMI countries, and LI countries. The results indicate that non-resident patents have a significant positive effect on TFP in All, UMI and LMI countries. It implies that non-resident patents contribute significantly to productivity of middle-income countries. The result of All countries is also derived from middle income countries. While the coefficient of non-resident patents is insignificant in the case of HI and LI countries. In HI countries, the existing level of technology is already high, thus additional contribution is not significant. In LI countries, factors such as lower absorptive capacity of domestic firms, weaker IPR, smaller markets discourage benefits from non-resident patents. As a result, there is no significant contribution to TFP.

The coefficient of lagged R&D is insignificant in all the cases. Here, the results support the argument by Griliches (1980) and Crepon et al. (1998) that the innovation input (R&D) contributes to innovation output (resident patents), not to the productivity of the firm or country. Thus, it is innovation output that influences the productivity of the country. Our results indicate the same. Here, the coefficient of R&D is not significant though we have used R&D lagged variable assuming that the effect of R&D investment will be reflected on TFP after few years. Using lagged variable also deals with the problem of simultaneity in the CDM model.

The resident patent variable has a significant positive effect on TFP in All countries and LMI countries. We used lagged variable to see the innovation output effect on productivity and to deal with the problem of simultaneity. The result implies that resident patent contributes significantly to TFP of LMI countries. In LMI countries, due to limited absorptive capacity, technological contributions to overall growth and productivity depends upon country’s own innovative capacity (or resident patents). While it does not contribute to the TFP of HI and LI countries. In HI countries, the possible interpretation of such a result is that patents may be skewed towards protecting incremental innovation, rather than breakthrough innovations that have the potential to significantly impact productivity growth. This could be due to the nature of the patent system, which may favor incremental innovations that are easier to define and defend. A firm level study by Hall and Ziedonis (2001) also find a similar result that patents are not a significant factor in explaining the productivity growth of the US pharmaceutical industry.

LI countries' result is insignificant, there may be several possibilities for such a result. First, LI countries may have weak institutional and legal frameworks to support effective IP protection and commercialization of innovations. As a result, even if residents do generate new ideas or technologies, they may not be able to profit from them and therefore may not be motivated to invest in further R&D. Second, lack the resources and infrastructure necessary to fully exploit new technologies, which can limit the overall impact of resident patents on productivity. Lastly, LI countries may rely more on imitation and adaptation of existing technologies rather than on original inventions. It is due to a lack of resources for R&D and limited access to knowledge and information. A study by Guloglu and Tekin (2014) finds that the strong impact of patents on productivity is much stronger in high-income countries.

In UMI countries resident patents are inversely related to TFP. A possible reason is that when firms are more focused on obtaining patents, they may devote less effort to improving their overall productivity or can be due to non-working of patents and strategic use of patents by firms. However, such an explanation would require further research. Another possibility is the presence of excess low-quality patents that do not contribute to innovation or productivity. A study by Long and Wang (2019) supports the above argument. They identified that the patent promotion polices (PPPs), have prompted the quantitative expansion of patent applications and approvals in China, but have had negative effects on average patent quality. However, this can be explored further at a firm level.

In contrast, FDI has no significant effect on TFP in all income levels. In HI countries the reason for the lack of significant effect of FDI on TFP is that these countries may already have a high level of technological advancement and knowledge spillovers. As a result, the additional technology and knowledge brought in by FDI may not have as significant an impact on TFP in these countries compared to in less developed countries. A study by Carkovic and Levine (2005) analysed the relationship between FDI and TFP using sample of 72 countries including HI countries and found no significant effect. The insignificant effect of FDI on TFP in UMI countries may be due to a combination of factors, including the level of absorptive capacity, competition and spillovers, and the type of FDI that flows into these countries. A study by Alfaro and Rodríguez-Clare (2004) analysed the impact of FDI on productivity in Latin American countries and found no significant effect. Further, the result shows that there is no significant effect of FDI on TFP in LMI countries. It may be due to multiple factors, including weak institutions, lack of complementary factors, and crowding-out effects. A study by Chakrabarti (2001) analysed the impact of FDI on productivity in Indian manufacturing firms and found no significant effect. Similar reasons apply to LI countries for insignificant FDI. A study by Abdullah and Chowdhury (2020) examines the impact of FDI on the TFP of 77 MI and LI countries. They find that FDI could not promote TFP in the countries studied. They stated that the lack of absorptive capacity is likely to be an important reason for not having a direct relationship between FDI and TFP. Further research would be necessary to fully understand the reasons behind this result.

The IPR index has a positive effect on TFP in All country group, with a stronger effect in HI and LI countries. It suggests that stronger patent protection leads to higher TFP growth. This result implies that when a country has a stronger patent system in place, it can encourage innovation by providing incentives for firms to invest in R&D. As a result, the increased level of innovation can lead to greater economic growth and productivity gains. Yang and Maskus (2001) found that stronger patent protection in OECD countries was positively associated with higher levels of FDI and economic growth. In case of LI countries such result indicates that low-income countries may face challenges in developing and adopting new technologies, stronger patent protection may provide the necessary incentives for firms and encourage to invest in innovation, which can lead to productivity gains. However, there is no significant impact of IPR on TFP of UMI and LMI countries. This result indicates that the relationship between patent protection and TFP is more complex in these countries, and other factors such as institutions, human capital, and access to financing may play a more significant role in driving productivity growth. A study by Rodriguez and Rodrik (2000) found that patent protection had a limited impact on economic growth in middle-income countries, as other factors such as education, infrastructure, and trade openness played a more significant role.

The results regarding the index of patent right and FDI are less consistent across existing studies. The relationship between the strength of a country's IPRs regime and rate of growth is ambiguous from a theoretical standpoint, reflecting the variety of channels through which technology can be acquired and their differing importance at different stages of development. Falvey et al. (2006) show that whilst the effect of IPR protection on growth depends upon the level of development, it is positively and significantly related to growth for LI and HI countries, but not for MI countries. Similarly, some studies have found a positive relationship between FDI and TFP (Borensztein et al., 1998), while others have found no significant relationship (Carkovic & Levine, 2005).

Finally, trade openness has significant impact on All countries and HI countries. It means that increased trade and globalization can lead to increased efficiency and productivity in these HI countries. When countries are open to trade, they can access a wider range of goods and services, which can lead to improvements in their existing technology, knowledge, and innovation. This can lead to a more efficient allocation of resources and ultimately boost productivity. Imbs and Wacziarg (2003) found that greater trade openness led to higher TFP in a sample of OECD countries. The coefficient of trade openness is negative and significant in the case of UMI, LMI and LI countries. In UMI countries, this result may be due to factors, such as weak institutions, limited access to capital and technology, and greater vulnerability to external shocks. Countries open for trade may face greater competition from other countries that have more advanced technology and better infrastructure, which can lead to the displacement of less productive firms and sectors. Additionally, increased trade can lead to greater exposure to global economic shocks, which can further hinder productivity growth. Bleaney and Wakelin (2002) also found that increased trade openness had a negative impact on TFP growth in a sample of UMI countries. Another study by Hye et al. (2016) found that trade openness had a negative impact on TFP growth in China, an UMI country, due to factors such as, low investment in human capital and physical, and limited access to technology.

Table 6.5: Results of TFP Equation

TFP	OLS_FE_All	OLS_FE_HI	OLS_FE_UM	OLS_FE_LM	OLS_FE_LI
PatAppNR	0.517**	-0.08	3.89***	6.42**	1593.122
	(2.04)	(-0.19)	(3.98)	(2.31)	(0.30)
L3RDexp	0.0113	0.000480	0.0249	-0.0248	0.283
	(1.32)	(0.05)	(0.88)	(-0.54)	(1.11)
L1PatAppRes	9.61e-08***	0.000000322	-0.000000100*	0.00000296*	0.000540
	(2.95)	(1.27)	(-1.84)	(1.67)	(0.14)
FDI	-0.0000408	-0.0000181	0.00148	0.00409	-0.00272
	(-0.56)	(-0.26)	(1.36)	(1.27)	(-0.58)
IPR	0.0219***	0.0393***	0.00165	0.0118	0.546**
	(2.77)	(2.79)	(0.15)	(0.60)	(2.58)
TO	0.000421***	0.000791***	-0.00101***	-0.00112*	-0.00604**
	(3.37)	(6.01)	(-2.94)	(-1.71)	(-2.92)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Pair fixed effects	Yes	Yes	Yes	Yes	Yes
Prob > chi 2	0.0000	0.0000	0.0000	0.0000	0.0000
_cons	0.837***	0.713***	0.987***	0.990***	-0.0194
	(24.63)	(11.18)	(22.52)	(12.44)	(-0.05)
N	825	498	211	101	15

Notes: *t* statistics in parentheses * $p < .10$, ** $p < .05$, *** $p < .01$

In the case of LMI countries, the negative and significant impact of trade openness on TFP implies that increased international trade may not necessarily lead to improved productivity in these countries. This could be due to various factors such as insufficient infrastructure, weak institutions, and limited human capital. Such countries may lack the necessary resources to fully exploit the benefits of increased trade.

Similar reasons applied on LI countries for negative and significant coefficient of trade openness. A study by Rodriguez and Rodrik (2000) and Kim (2011) also found that trade liberalization did not necessarily lead to increased productivity in developing countries.

6.2 Discussion

In this chapter, we examine non-resident patenting as a contributing factor to R&D decision and R&D expenditure, resident patenting, and total factor productivity of a country. We used sample of 188 countries which includes HI, UMI, LMI, and LI countries. First, we estimated the results on full sample and then on sub samples. We find that non-resident patents are positively related to R&D decision, R&D investment, resident patents, and total factor productivity in case of all countries, UMI countries and LMI income countries. In the case of HI countries, non-resident patents are positively related to resident patents. Lastly, non-resident patents are negatively associated with R&D decision and R&D expenditure of LI income countries.

The impact of foreign patenting on R&D, domestic patenting, and total factor productivity can vary across countries with different income levels. In the case of HI countries, our results are contradictory to the previous study done by Chen and Puttitanun (2005). It shows that foreign patenting can have a positive impact on R&D and TFP in high-income countries. However, our shows no impact of foreign patents on R&D and TFP. Further, a study by Guellec and van Pottelsberghe de la Potterie (2004) indicates that foreign patenting can decrease the number of domestic patents filed in HI countries. Our results show a positive and significant relation between these two in HI countries. The impact of foreign patenting on R&D, domestic patenting, and TFP in LI countries is generally negative or insignificant. We also find similar results. Park and Ginarte (1997), found that foreign patenting has a negative impact on R&D investment in LI countries. Similarly, the same study found that foreign patenting has a negative impact on domestic patenting in these countries. However, our study finds no impact of non-resident patents on domestic patents and TFP of LI countries.

Chapter 7

Summary and Conclusion

7.0 Introduction

The previous chapter presented the result of the CDM model with R&D, patent and TFP as the dependent variables. It highlighted the influence of foreign patenting on host countries' innovation and productivity. The chapter also explained the impact of foreign patenting on different country groups such as high income, upper-middle income, lower-middle income and low-income countries. This chapter summarises the overall thesis followed by its key findings, policy recommendations, limitations of the study and concluding remarks.

7.1 Summary

Non-resident patenting is an important aspect of international technology transfer, and it has become increasingly important in recent years as globalization has led to a more interconnected world order. The number of patent applications filed worldwide increased from 959,764 in 2001 to 3,330,000 in 2019, representing a growth of approximately 247% (WIPO, 2020). This significant increase can be attributed to the globalization, the rise of emerging markets, and the advancement of technology. During this period the geographic distribution of patent filings has also been changed. In 2001, most of the patent applications originated from the developed countries such as the US, Japan, and European countries (Germany, France etc.). However, in recent years, there has been a significant increase in patent applications filed in emerging economies, such as China, Korea, and India. This shift reflects the growing importance of innovation in emerging countries as they also compete in the global market.

This thesis explores the concept of non-resident patenting and its importance. Further, it evaluates the determinants of foreign patenting and its impact on patent recipient countries. One of the primary reasons for seeking patent protection in foreign countries is to prevent others from copying or reproducing an invention. Without patent protection, competitors can freely enter a market and use a similar product, leading to lost revenue and market share for the original inventor. Patent protection can offer a dual benefit of creating a competitive edge by preventing competitors from entering the market, while also generating licensing income for the patent holder. Previous literature has highlighted the importance of foreign patenting for protecting intellectual property, expanding operations, creating licensing opportunities, and providing a defensive tool against potential litigation. While there are challenges associated with foreign patenting, it remains a critical tool for businesses seeking to compete and succeed in a globalised economy.

The first part of this thesis investigates the impact of a home country's technological capabilities as a key determinant on its outbound foreign patenting using a panel data set of 122 countries from 2001 to 2019. Further, we also investigate the influence of technological gap of the host country (from technology frontier country in terms of technological capabilities) on the inflow of foreign patenting in that country. We construct a technology index using both input and output indicators of innovation to analyse the technological capabilities of a country that contributes toward its patent seeking and filing capacity across countries. So far, in our knowledge, previous research has not examined such influence on countries' cross-country patenting activities. For empirical purpose, we used gravity model framework to examine the bilateral flow of patent applications between source and destination countries.

The latter part of the thesis investigates the relationship between foreign patenting and innovation efforts, and how it impacts productivity in developed and developing countries. Using a sample of 188 countries from 2001 to 2019, we explore how technology transfer channels contribute to total factor productivity growth and innovation. We adopt the Crepon, Duguet, and Mairesse (1998) model to analyse a country's innovation decision, R&D investment, patent applications, and the overall impact on productivity. First, we estimated the impact of foreign patenting on aggregate level (full sample of 188) and then estimated the same on the sub samples of different country groups such as high income, upper middle income, lower middle income, and low-income countries.

7.2 Key Findings

A short summary of the research findings of each objective is presented below:

Objective 1: To investigate the technological capabilities of patent source country and technology gap between the patent source and destination countries, that induce the cross-country patenting activity.

H$_1$: *Home country's technological capability is positively related to the patents applied in other countries.*

H$_2$: *Technological gap between two countries is inversely related to the patents applied in other countries.*

Foreign Patenting Equation

$$FORPAT_{ijt} = \beta TI_{it} + \beta_1 LnGDPPC_{jt} + \beta_2 LnGDPPC_{it} + \beta_3 IPR_{jt} + \beta_4 TechGap_{ijt} + \beta_5 Contig_{ij} + \beta_6 ComnLang_{ijt} + \beta_7 ColTies_{ijt} + \beta_8 IPR_{jt} TI_{it} + EPOHH_{ijt} + \pi_{ij} + \pi_t + \varepsilon_{ijt} \quad (2)$$

- Our results provide strong evidence that technological capabilities encourage innovative activities within the country and patenting in the host country.
- Higher technological capabilities increase the likelihood that inventors become motivated to patent more in other countries that offer lucrative markets.
- A higher technological gap discourages an innovative country from patenting in other countries.

Objective 2: To explore the influence of non-resident patents on R&D investment of the host countries.

H$_3$: *Non-resident patenting is positively related to the host country's innovation input (R&D intensity)*

R&D Equations

$$DRD_{it}^{*} = b_0 PatAppNR_{it} + b_1 GDPPC_{it} + b_2 IPR_{it} + b_3 TO_{it} + u_{it} \tag{7a}$$

$$RDexp_{it} = b_0 SchoolEnrol_{it} + b_1 PatAppNR_{it} + b_2 GDPPC_{it} + b_3 IPR_{it} + b_4 TO_{it} + u_{0i} \tag{7b}$$

- Non-resident patents have a positive effect on R&D decision as well as on R&D expenditure.
- At disaggregate level, non-resident patents have no impact on R&D decision and R&D expenditure of high-income countries.
- Non-resident patents are inversely related to R&D expenditure in low-income countries.

Objective 3: To examine the impact of international patents on the resident patents of the host country.

H$_4$: *Non-resident patenting is positively related to the host country's innovation output (Resident patenting)*

Patent Equation

$$PatAppR_{it} = a_i Lag3RDexp_{it} + b_0 PatAppNR_{it} + b_1 GDPPC_{it} + b_2 IPR_{it} + b_3 FDI_{it} + Country\ Dummies_i + Year\ Dummies_t + u_{it} \tag{8}$$

- Non-resident patents have a significant impact on resident patenting except low-income countries.
- The impact of non-resident patents is higher in lower-middle income countries than high income and upper middle-income countries.

- Non-resident patents are an important source of technology access for domestic firms and innovators. However, in low-income countries due to low absorptive capacity domestic firms do not get such benefits.

Objective 4: To study the non-resident patenting as an important driver of total factor productivity of the host country.

H₅: *Non-resident patenting is positively related to the host country's productivity (Total factor productivity)*

Total Factor Productivity Equation

$$TFP_{it} = a_i lag1PatAppR_{it} + b_0 Lag3RDexp_{it} + b_1 PatAppNR_{it} + +b_2 FDI_{it} + b_3 IPR_{it} + b_4 TOsq_{it} + Country\ Dummies_i + Year\ Dummies_t + u_{it} \quad (9)$$

- Non-resident patents have a positive and significant impact on total factor productivity.
- At a disaggregate level, there is no impact of non-resident patents on total factor productivity of high income and low-income countries. It mostly affects the middle-income countries.
- There is no direct impact R&D on a country's total factor productivity. It is the innovation output (resident patents) that influences the productivity of the country.

Table 7.1: Summary of Results of Objective 1			
Dependent Variable	ForeignPat	ForeignPat	ForeignPat
Independent Variables	All_to_All	HI_to_All	MI_to_All
TIHome	Positive and highly significant	Positive and highly significant	Positive and highly significant
TechDistTIHost	Negative and highly significant	Insignificant	Negative and highly significant
lnGDPPCHost	Positive and highly significant	Positive and highly significant	Positive and significant
lnGDPPCHome	Positive and highly significant	Positive and highly significant	Positive and highly significant
Contig	Positive and highly significant	Positive and highly significant	Positive and highly significant
ComnLang	Positive and highly significant	Positive and highly significant	Positive and highly significant
ColTies	Insignificant	Insignificant	Insignificant
IPRHost	Positive and highly significant	Positive and highly significant	Negative and significant
IPRTI	Positive and highly significant	Positive and highly significant	Positive and highly significant
EPOHH	Negative and highly significant	Negative and highly significant	Insignificant

Table 7.2: Summary of Results of Objective 1				
Dependent Variable	ForeignPat	ForeignPat	ForeignPat	ForeignPat
Independent Variables	HI to MI	MI to HI	HI to HI	MI to MI
TIHome	Insignificant	Insignificant	Positive and highly significant	Negative and highly significant
TechDistTIHost	Negative and Significant	Negative and Significant	Insignificant	Negative and highly significant
lnGDPPCHost	Positive and highly significant	Positive and highly significant	Positive and highly significant	Positive and highly significant
lnGDPPCHome	Positive and highly significant	Positive and highly significant	Positive and highly significant	Positive and highly significant
Contig	Insignificant	Insignificant	Positive and highly significant	Insignificant
ComnLang	Positive and highly significant	Positive and highly significant	Positive and highly significant	Positive and highly significant
ColTies	Insignificant	Insignificant	Positive and Significant	Insignificant
IPRHost	Negative and highly significant	Negative and highly significant	Insignificant	Positive and Significant
IPRTI	Positive and highly significant	Positive and highly significant	Positive and highly significant	Positive and highly significant
EPOHH	Insignificant	Insignificant	Negative and highly significant	Insignificant

Table 7.3: Summary of Results of Objective 2					
Dependent Variable	R&Dexp	R&Dexp	R&Dexp	R&Dexp	R&Dexp
Independent Variables	All	HI	UM	LM	LI
PatAppNR	Positive and significant	Insignificant	Positive and highly significant	Insignificant	Negative and highly significant
IPR	Positive and significant	Insignificant	Insignificant	Insignificant	Insignificant
GDPPC	Positive and highly significant	Positive and significant	Positive and highly significant	Negative and significant	Positive and significant
TO	Negative and highly significant	Insignificant	Positive and highly significant	Insignificant	Positive and significant
_cons	Insignificant	Insignificant	Negative and significant	Positive and significant	Insignificant
Dependent Variable	RDDummy	RDDummy	RDDummy	RDDummy	RDDummy
Independent Variables	All	HI	UM	LM	LI
SchoolEnrol	Positive and significant	Insignificant	Insignificant	Insignificant	Negative and significant
PatAppNR	Positive and highly significant	Insignificant	Positive and highly significant	Positive and highly significant	Positive and highly significant
GDPPC	Insignificant	Negative and highly significant	Insignificant	Positive and highly significant	Insignificant
IPR	Positive and highly significant	Positive and highly significant	Positive and highly significant	Insignificant	Positive and significant
TO	Positive and significant	Positive and highly significant	Negative and highly significant	Insignificant	Negative and highly significant
/mills Lambda	Negative and highly significant	Insignificant	Negative and highly significant	Negative and significant	Insignificant

Table 7.4: Summary of Results of Objective 3					
Dependent Variable	PatAppRes	PatAppRes	PatAppRes	PatAppRes	PatAppRes
Independent Variables	All	HI	UM	LM	LI
PatAppNR	Positive and highly significant	Positive and highly significant	Positive and highly significant	Positive and highly significant	Insignificant
L3RDexp	Positive and highly significant	Positive and highly significant	Positive and highly significant	Insignificant	Insignificant
GDPPC	Positive and highly significant	Positive and highly significant	Positive and highly significant	Positive and highly significant	Negative and significant
FDI	Negative and significant	Negative and significant	Insignificant	Insignificant	Insignificant
IPR	Positive and highly significant	Positive and highly significant	Positive and significant	Insignificant	Insignificant

Table 7.5: Summary of Results of Objective 4					
Dependent Variable	TFP	TFP	TFP	TFP	TFP
Independent Variables	ALL	HI	UM	LM	LI
PatAppNR	Positive and significant	Insignificant	Positive and highly significant	Positive and significant	Insignificant
L3RDexp	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
L1PatAppRes	Positive and highly significant	Insignificant	Negative and significant	Positive and significant	Insignificant
FDI	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
IPR	Positive and highly significant	Positive and highly significant	Insignificant	Insignificant	Positive and significant
TO	Positive and highly significant	Positive and highly significant	Negative and highly significant	Negative and significant	Negative and significant

7.3 Discussion of Results

This thesis discusses the contributing factors to inward foreign patenting in the host countries. Additionally, it also examines non-resident patenting as a key driver of innovation and productivity of a country. It is hypothesised that technological capabilities of home countries influence their outward foreign patenting in the host countries that further stimulates the technology trade. We have empirically shown that a home country's technological capabilities positively stimulate foreign patenting flow in case of All to All, HI to All, and HI to HI countries. However, technological capabilities of home country are inversely related to non-resident patent flows in case of MI to All and MI to MI. Here, aggregate results are derived from a particular group of countries. The positive and significant coefficient of technological capabilities is derived from HI country group and negative significant coefficient is derived from MI countries. Such a result shows that technological capabilities is an important indicator of the role that technology plays in global innovation and economic development. Here, relationship of technological capabilities of a patent originating country and its patenting flow to a recipient country holds true across all country samples, indicating that countries with more advanced technological capabilities are more likely to produce and attract foreign patents. This relationship is particularly strong among HI countries, where technological development is most concentrated. For example, countries such as the US, Japan, and Germany have a large number of highly skilled researchers, well-funded research institutions, and robust intellectual property systems that incentivise innovation and facilitate technology transfer. These countries are major producers of high-tech inventions, and they also attract significant flows of non-resident patents from other countries seeking access to their advanced technologies.

Further, the finding that the technological capabilities of MI (patent originating) countries are negatively related to their patenting flow to All (patent recipient) countries is somewhat counterintuitive. It suggests that countries with more advanced technological capabilities may not necessarily be more attractive destinations for foreign patenting in all contexts particularly for MI countries. It suggests that despite MI countries' technological capabilities, these countries may face significant barriers in leveraging their knowledge and expertise to create and export intellectual property. They may still struggle to compete with HI countries in terms of exporting their intellectual property due to factors such as weaker domestic intellectual property systems, limited access to funding for research and development, and lower levels of innovation and entrepreneurship. For example, MI countries such as China, India, and Brazil may have significant technological capabilities, but they still face challenges in exporting their intellectual property due to factors such as inadequate intellectual property protection and enforcement, limited access to financing for innovation, and insufficient support for entrepreneurship and commercialization. As discussed above, there are variations in the technological capabilities of MI countries that are captured through the index. However, the aggregate behaviour as reflected by the index needs to be further analysed, which remains for future work.

Further, the present study examines the impact of technological gap on international patenting, the reverse causality has been explored in earlier studies (Hafner, 2008; Park, 2013). Our empirical finding shows that technological gap between a patent recipient country and a country with a high technology index have an inverse relationship with its inward foreign patenting. It means that as the technological gap between the two countries decreases, the likelihood of the patent recipient country receiving foreign patents increases. There are several reasons for this relationship. First, as a country's technology level increases, it becomes more attractive to foreign patent holders who may seek to expand their patent portfolios. Second, as a country's technology level increases, it may have more resources to invest in research and development, which can lead to more patents being granted domestically. Third, a country with a high technology index may have more stringent patent laws, which can make it more difficult for foreign patent holders to obtain patents in that country. In the case of HI to All and HI to HI technological gap has no significant impact on non-resident patenting flow. In general, it is true that a HI country with a strong technological base might not necessarily have a high level of inward foreign patenting. For example, the US is a world leader in technological innovation and has a high level of patenting activity, but it is not the leading country in terms of inward foreign patenting.

Instead, countries such as Japan, China, and Germany are major patent recipients from other countries. Our findings align closely with earlier theoretical studies that have argued that technologically lagging countries might encounter a drawback due to their limited absorptive capacity. Consequently, the existing technology gap could hinder their ability to learn and engage effectively in international technology diffusion, as elucidated in prior works by Aghion et al. (2005), Castellacci (2011), and Popp (2006).

Our future research seeks to examine this relationship where technological gap should be measured by difference between host and home countries in terms of technology index. The present study is used technological gap of host country from country with highest technology index in a particular year.

We have approached the problem from both host and home country's (bilateral) perspective and exposed variations in factors determining cross-country patenting. Further, as all economies in our sample have implemented patent policy changes to comply with TRIPs, our study offers empirical evidence about the impact of agreement on patenting. Even with its limitations, this study makes several important contributions to literature on innovation and economic growth at a country level. Although most studies discussed innovation focusing on firm-level or industry-level innovation, our study analyses country-level innovation. In addition, it incorporates a comprehensive and large data set of HI and MI countries that allows for bilateral panel data analysis. Past studies at country level either focused on OECD or highly industrialised economies (Raghupathi & Raghupathi, 2017).

We also examined non-resident patenting as one of the important determining factors of country's innovation and productivity and also the relationship among these three. We analysed the impact of non-resident patenting on innovation input and innovation output both. We find that non-resident patenting influences total factor productivity of the country through two channels. First, it affects TFP directly. Second, indirect channel affects resident patenting of a country and resident patenting affects TFP. However, the impact of direct channel is higher. There is no impact of R&D (innovation input) on TFP though non-resident patenting affects R&D.

At a disaggregate level, the relationship between non-resident patenting and R&D investment can vary depending on a country's income level. Our findings show that there is a significant impact on R&D investment in UMI countries, no impact in HI countries, and an inverse relationship in LI countries. UMI countries are more likely to rely on foreign technology and knowledge to drive innovation and economic growth. Thus, non-resident patenting can have a significant impact on their R&D investment. For example, China is an UMI country that has seen a considerable increase in foreign patent filings over the years. This has resulted in increased R&D investment by Chinese firms as they seek to compete globally. In HI countries, there is already a high level of investment in R&D, and non-resident patenting does not have a significant impact. These countries have well-established research institutions and a highly skilled workforce, which reduces their reliance on foreign technology. For example, the US is a HI country that is home to some of the world's top research institutions, and its companies invest heavily in R&D. In LI countries, there is an inverse relationship between non-resident patenting and R&D investment. This is because these countries often lack the resources and capabilities to develop and commercialise their innovations. Non-resident patenting can lead to a situation where foreign firms capture a significant share of the market, making it difficult for local firms to invest in R&D. For example, many African countries are LI countries that rely heavily on foreign technology and face challenges in developing and commercializing their own innovations.

Our results also suggest that non-resident patenting have a significant impact on resident patenting in all income groups except LI countries. It suggests that the presence of foreign inventors and companies can lead to increased innovation and patenting activity among domestic inventors and firms, but this effect may not hold true in the case of the least developed economies. In HI countries like Germany, the presence of foreign inventors and companies may stimulate competition and collaboration among domestic inventors and firms, leading to increased innovation and patenting activity. Similarly, in UM and LM income countries, local firms get benefited from foreign technology exposure. Whereas LI countries, lack necessary infrastructure and resources to fully leverage the benefits of non-resident patenting. For instance, they may have weak legal systems that do not adequately protect intellectual property rights, making it more difficult for domestic inventors and firms to benefit from the presence of foreign patent holders. Additionally, they may not have the same level of access to capital, technology, or skilled labor as HI countries, which can limit their ability to compete in the global marketplace and innovate.

Finally, we observe that non-resident patenting has a positive impact on total factor productivity of full sample. This result is derived from UM and LM income countries. There is no impact of non-resident patenting on TFP of HI and LI countries. It suggests that the effect of non-resident patenting on productivity may vary depending on the level of economic development. The possible explanation of this result is that non-resident patenting may be more beneficial in countries where there is a larger pool of skilled labor and technological capabilities such as China and India. Whereas in HI countries, for example, there may already be a high level of technological development and innovation, and therefore the impact of non-resident patenting on TFP may be minimal. Similarly, in LI countries, the lack of access to capital and technology may limit the potential benefits of non-resident patenting.

These findings suggest that promoting international knowledge flows and protecting intellectual property rights can stimulate R&D expenditure and innovation activities. Policymakers should consider different policy interventions to promote innovation in different income groups, and the drivers of TFP can differ based on the level of development of a country.

7.4 Synthesis of Findings

We have synthesised our empirical findings that are elaborately discussed in chapters 5 and 6 to understand the determinants of non-resident patenting and its impact on R&D, resident patenting, and total factor productivity of developed and developing countries. One common finding among objectives two, three and four is that the impact of non-resident patenting on innovation and productivity depends upon country's existing level of technological development. However, objective one finds the impact of technological capabilities of home countries and technology gap of host countries are two important determinants of non-resident patenting.

Our results provide strong evidence that technological capabilities encourage innovative activities within the country and patenting in the host country. Higher technological capabilities increase the likelihood that inventors become motivated to patent more in other countries that offer lucrative markets. Also, with respect to the technological gap, we found that a higher technological gap discourages an innovative country from patenting in other countries. Hence, it appears that technological capabilities and technological gap are be the determining factors for patenting in foreign countries provided a minimum level of economic development of a country. We also examine the interaction between home countries' technology index and the host countries' patent rights protection. The coefficient of interaction is positively significant across all country groups. It indicates that keeping IPR constant, increase in TI will positively affect the non-resident patents inflow in the host country.

Our findings also suggest that foreign patenting positively impacts innovation and productivity in both developed and developing countries. Using CDM model, our first equation used a Heckman's selection model and found that non-resident patents have a positive effect on R&D decision as well as on R&D expenditure. However varying effect on disaggregation level depends upon the existing level of technology. For example, in HI countries the coefficient of non-resident patenting is insignificant, it indicates that the existing level of technology is already high therefore the additional contribution is not significant.

In the case of domestic patenting, the coefficient of non-resident patenting is positive and significant across all country groups except LI countries. It implies that non-resident patents are an important source of technology access for domestic firms and innovators (Maskus, 2004). The local firms get the opportunity to study the underlying technology in those applications and invent new products or processes parallel to that technology avoiding the infringement. It further motivates domestic patenting activities. While in LI countries due to low absorptive capacity domestic firms do not get such benefits.

Finally, in the TFP equation we find that non-resident patenting has a positive and significant impact on TFP for full sample while varying effect on country subgroups. It is due to other characteristics of the countries such as existing technology level, absorptive capacity, patent rights policy, FDI policies etc. Here, the results support the argument by Griliches (1980) and Crepon et al. (1998) that the innovation input (R&D) contributes to innovation output (resident patents), not to the productivity of the firm or country. Thus, it is innovation output that influences the productivity of the country. Our results indicate the same. In productivity equation results, coefficient of R&D is not significant though we have used R&D lagged variable assuming that the effect of R&D investment will be reflected on TFP after few years. Using lagged variable also deals with the problem of simultaneity in the CDM model.

7.5 Policy Recommendations

Based on the empirical findings we provide recommendations for innovation and technology policies based on countries' development levels. The study suggests that policymakers should consider different policy interventions to promote innovation in different income groups and that the drivers of TFP can differ based on the level of development of a country.

The lower middle income and low-income countries need to prioritize the improvement of their technological capabilities. This not only facilitates the creation of new products and processes, but also attracts foreign technologies to their shores. To achieve this, such countries should increase their investment in research and development, with a focus on producing more patented technologies and scientific journal articles. This will not only enhance their technological capabilities, but also boost their absorptive capacity to effectively adopt and adapt to new technologies. By enhancing their technological capabilities, these countries can position themselves as attractive destinations for foreign investment, while also fostering innovation and growth domestically.

At international forum developing countries can promote economic development and technological advancement by prioritizing and facilitating technology transfer. Such a policy should be grounded in the principles outlined in the TRIPS Agreement on Technology Transfer and should aim to strike a balance between the rights of technology holders and the obligations of technology recipients while prioritizing access to technology, capacity-building, and technology diffusion. Additionally, to access the international market, lower middle-income countries must improve the quality of their patents. This will enable them to compete effectively and gain market share.

Upper middle-income countries can reinforce the support mechanisms for foreign patents by strengthening their patent offices to boost their R&D activities. This will facilitate the positive impact of foreign patenting on R&D expenditure in these countries. Low-income countries must explore alternative sources of funding to increase their expenditures on R&D as they may not have sufficient financial resources to support R&D activities.

At international level, it is clear that impact of foreign patent is contingent on the absorptive capacity of individual countries, and as such, may not necessarily have a positive effect on low-income countries in terms of resident patenting, total factor productivity, or R&D expenditure. Consequently, these countries need to explore alternative methods or mechanisms for technology transfer, such as international collaborations or funding for R&D, to build their domestic capabilities.

7.6 Contribution of the Study

Even with its limitations, this study makes several important contributions to literature on innovation and economic growth at a country level. Although, most studies discussed innovation focusing on firm-level or industry-level innovation, our study analyses country-level innovation. This study focuses on two different aspects of non-resident patenting activities of developed and developing economies. First, factors influencing non-resident patenting in these economies. Here, this study contributes to the existing literature focusing on international trade and technology diffusion in many ways (a) Introducing technological capabilities of home countries and technological gap of host countries as key determinants (b) We have constructed technology index to use as a proxy variable of technological capabilities. Also measured technology gap using the technology index values (c) We used gravity model framework to explore bilateral patenting flows instead trade flows.

Second, we have examined non-resident patenting as a key determinant of innovation and productivity in developed and developing economies using CDM framework. Here, following are our contributions to the existing literature (a) We have applied CDM framework on country level data instead firm level data (b) We have used a variant of CDM model by introducing non-resident patenting as a key component. Lastly, we reconcile the literature from two different strands i.e., the international trade literature and international business literature. In addition, it incorporates a comprehensive and large data set of HI, UMI, LMI and LI (188) countries that allows for panel data analyses. Past studies at country level either focused on OECD or highly industrialised economies.

7.7 Limitations and Future Research

The present study explores the non-resident patenting as a dependent variable as well as independent variable in empirical investigation. Due to missing data or data reporting issues our findings are based on limited data particularly non-resident patent application count data. We have avoided using zero for missing values to maintain the originality of the results. Because in count data zero is also an information indicates that country has not filed any patent in that particular year. Also, our sample is also based on availability of the data of key variables of interests.

As discussed in the previous section that there are variations in the technological capabilities of middle-income countries that are captured through the index and our results are based on aggregate data. However, the aggregate behaviour as reflected by the index needs to be further analysed, which remains for future work. Our future research also seeks to examine the relationship of non-resident patents and technological gap where technological gap should be measured by difference between host and home countries in terms of technology index. The present study is used technological gap of host country from country with highest technology index in a particular year.

Further, we examine the overall impact of foreign patenting on R&D, domestic patenting, and TFP and find that it can vary across countries with different income levels. However, it is positive and significant in all three equations for full country sample that supports our hypothesis. The varying effect in country sub groups as per their income levels can be further analysed using country specific controls. Also, country specific firm level studies may give better understanding of influence of non-resident patenting. It remains as a future work.

7.8 Concluding Remarks

In this doctoral dissertation, we have approached the issue of international patenting from both host and home country's (bilateral) perspective and find variations in factors determining cross-country patenting. Further, as all economies in our sample have implemented patent policy changes to comply with TRIPs, our study offers empirical evidence about the impact of agreement on patenting.

Our results provide strong evidence that technological capabilities encourage innovative activities within the country and patenting in the host country. Higher technological capabilities increase the likelihood that countries become motivated to patent more in the countries that offer lucrative markets. Also, with respect to the technological gap, we find that a higher technological gap discourages an innovative country from patenting in other countries.

Hence, it appears that technological capabilities and technological gap are important determining factors for patenting in foreign countries provided a minimum level of economic development.

The overall impact of foreign patenting on R&D, domestic patenting, and TFP can vary across countries with different income levels. The findings suggest that promoting international knowledge flows and protecting intellectual property rights can stimulate R&D expenditure, innovation activities and productivity. Policymakers should consider different policy interventions to promote innovation in different income groups, and the drivers of TFP can differ based on the level of development of a country.

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Appendix A List of Countries

S.No.	Country Name	Income Group	S.No.	Country Name	Income Group
1	Afghanistan	LI	41	Congo, Rep.	LMI
2	Albania	UMI	42	Costa Rica	UMI
3	Algeria	LMI	43	Cote d'Ivoire	LMI
4	American Samoa	UMI	44	Croatia	HI
5	Angola	LMI	45	Cuba	UMI
6	Antigua and Barbuda	HI	46	Curacao	HI
7	Argentina	UMI	47	Cyprus	HI
8	Armenia	UMI	48	Czech Republic	HI
9	Aruba	HI	49	Denmark	HI
10	Australia	HI	50	Dominica	UMI
11	Austria	HI	51	Dominican Republic	UMI
12	Azerbaijan	UMI	52	Ecuador	UMI
13	Bahamas	HI	53	Egypt, Arab Rep.	LMI
14	Bahrain	HI	54	El Salvador	LMI
15	Bangladesh	LMI	55	Eritrea	LI
16	Barbados	HI	56	Estonia	HI
17	Belarus	UMI	57	Eswatini	LMI
18	Belgium	HI	58	Ethiopia	LI
19	Belize	UMI	59	Fiji	UMI
20	Benin	LMI	60	Finland	HI
21	Bermuda	HI	61	France	HI
22	Bhutan	LMI	62	Gabon	UMI
23	Bolivia	LMI	63	Gambia	LI
24	Bosnia and Herzegovina	UMI	64	Georgia	UMI
25	Botswana	UMI	65	Germany	HI
26	Brazil	UMI	66	Ghana	LMI
27	Brunei Darussalam	HI	67	Greece	HI
28	Bulgaria	UMI	68	Greenland	HI
29	Burkina Faso	LI	69	Grenada	UMI
30	Burundi	LI	70	Guam	HI
31	Cabo Verde	LMI	71	Guatemala	UMI
32	Cambodia	LMI	72	Guinea	LI
33	Cameroon	LMI	73	Haiti	LMI
34	Canada	HI	74	Honduras	LMI
35	Central African Republic	LI	75	Hong Kong SAR, China	HI
36	Chad	LI	76	Hungary	HI
37	Chile	HI	77	Iceland	HI
38	China	UMI	78	India	LMI
39	Colombia	UMI	79	Indonesia	LMI
40	Congo, Dem. Rep.	LI	80	Iran, Islamic Rep.	LMI

S.No.	Country Name	Income Group	S.No.	Country Name	Income Group
81	Iraq	UMI	121	Myanmar	LMI
82	Ireland	HI	122	Namibia	UMI
83	Israel	HI	123	Nauru	HI
84	Italy	HI	124	Nepal	LMI
85	Jamaica	UMI	125	Netherlands	HI
86	Japan	HI	126	New Zealand	HI
87	Jordan	UMI	127	Nicaragua	LMI
88	Kazakhstan	UMI	128	Niger	LI
89	Kenya	LMI	129	Nigeria	LMI
90	Kiribati	LMI	130	North Macedonia	UMI
91	Korea, Dem. People’s Rep.	LI	131	Norway	HI
92	Korea, Rep.	HI	132	Oman	HI
93	Kuwait	HI	133	Pakistan	LMI
94	Kyrgyz Republic	LMI	134	Panama	HI
95	Lao PDR	LMI	135	Papua New Guinea	LMI
96	Latvia	HI	136	Paraguay	UMI
97	Lebanon	LMI	137	Peru	UMI
98	Lesotho	LMI	138	Philippines	LMI
99	Liberia	LI	139	Poland	HI
100	Libya	UMI	140	Portugal	HI
101	Liechtenstein	HI	141	Puerto Rico	HI
102	Lithuania	HI	142	Qatar	HI
103	Luxembourg	HI	143	Romania	HI
104	Macao SAR, China	HI	144	Russian Federation	UMI
105	Madagascar	LI	145	Rwanda	LI
106	Malawi	LI	146	Samoa	LMI
107	Malaysia	UMI	147	San Marino	HI
108	Maldives	UMI	148	Sao Tome and Principe	LMI
109	Mali	LI	149	Saudi Arabia	HI
110	Malta	HI	150	Senegal	LMI
111	Marshall Islands	UMI	151	Serbia	UMI
112	Mauritania	LMI	152	Seychelles	HI
113	Mauritius	UMI	153	Sierra Leone	LI
114	Mexico	UMI	154	Singapore	HI
115	Moldova	UMI	155	Slovak Republic	HI
116	Monaco	HI	156	Slovenia	HI
117	Mongolia	LMI	157	South Africa	UMI
118	Montenegro	UMI	158	Spain	HI
119	Morocco	LMI	159	Sri Lanka	LMI
120	Mozambique	LI	160	St. Lucia	UMI

S.No.	Country Name	Income Group	S.No.	Country Name	Income Group
161	St. Vincent and the Grenadines	UMI	175	Ukraine	LMI
162	Sudan	LI	176	United Arab Emirates	HI
163	Sweden	HI	177	United Kingdom (UK)	HI
164	Switzerland	HI	178	United States (US)	HI
165	Syrian Arab Republic	LI	179	Uruguay	HI
166	Tajikistan	LMI	180	Uzbekistan	LMI
167	Tanzania	LMI	181	Vanuatu	LMI
168	Thailand	UMI	182	Venezuela, RB	LMI
169	Togo	LI	183	Vietnam	LMI
170	Trinidad and Tobago	HI	184	Virgin Islands (U.S.)	HI
171	Tunisia	LMI	185	West Bank and Gaza	LMI
172	Turkey	UMI	186	Yemen, Rep.	LI
173	Turkmenistan	UMI	187	Zambia	LI
174	Uganda	LI	188	Zimbabwe	LMI

Appendix B Technology Index

Country Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
South Korea	0.52	0.59	0.61	0.63	0.65	0.68	0.68	0.69	0.70	0.73	0.75	0.76	0.79	0.81	0.80	0.78	0.81	0.82	0.81	0.72
Japan	0.67	0.76	0.70	0.66	0.66	0.64	0.61	0.61	0.59	0.59	0.59	0.55	0.56	0.56	0.53	0.52	0.53	0.52	0.49	0.60
Finland	0.33	0.35	0.38	0.65	0.64	0.61	0.57	0.59	0.60	0.60	0.58	0.54	0.55	0.53	0.50	0.47	0.47	0.47	0.45	0.52
Sweden	0.56	0.15	0.59	0.56	0.58	0.56	0.48	0.51	0.48	0.47	0.46	0.45	0.52	0.51	0.51	0.50	0.51	0.50	0.48	0.50
Denmark	0.37	0.50	0.46	0.45	0.45	0.44	0.43	0.48	0.50	0.50	0.51	0.50	0.52	0.53	0.53	0.53	0.51	0.50	0.47	0.48
Singapore	0.38	0.49	0.47	0.49	0.50	0.48	0.46	0.47	0.44	0.43	0.43	0.40	0.43	0.43	0.44	0.42	0.41	0.40	0.39	0.44
Slovenia	0.33	0.40	0.40	0.39	0.44	0.42	0.39	0.43	0.44	0.45	0.49	0.44	0.46	0.44	0.42	0.39	0.40	0.42	0.40	0.42
Germany	0.38	0.44	0.42	0.41	0.41	0.40	0.38	0.40	0.41	0.41	0.41	0.40	0.42	0.41	0.42	0.41	0.43	0.42	0.41	0.41
United States	0.39	0.45	0.43	0.41	0.41	0.40	0.38	0.39	0.40	0.39	0.39	0.37	0.39	0.39	0.39	0.38	0.39	0.39	0.38	0.39
Israel	0.41	0.44	0.46	0.49	0.47	0.47	0.41	0.41	0.38	0.36	0.35	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.33	0.39
Austria	0.19	0.37	0.25	0.36	0.38	0.37	0.36	0.38	0.38	0.40	0.39	0.40	0.42	0.43	0.43	0.42	0.42	0.42	0.40	0.38
Czechia	0.25	0.30	0.32	0.34	0.36	0.37	0.35	0.36	0.34	0.35	0.35	0.35	0.38	0.41	0.42	0.39	0.39	0.39	0.37	0.36
Iceland	0.48	0.27	0.51	0.10	0.52	0.53	0.47	0.47	0.49	0.09	0.46	0.07	0.37	0.19	0.40	0.41	0.38	0.38	0.18	0.36
Canada	0.35	0.42	0.40	0.41	0.41	0.40	0.38	0.39	0.37	0.37	0.36	0.33	0.34	0.34	0.33	0.32	0.32	0.32	0.16	0.35
Belgium	0.32	0.36	0.34	0.34	0.34	0.34	0.32	0.33	0.32	0.33	0.34	0.34	0.36	0.37	0.37	0.37	0.37	0.38	0.38	0.35
Netherlands	0.30	0.35	0.34	0.35	0.35	0.35	0.31	0.31	0.30	0.31	0.33	0.33	0.39	0.39	0.38	0.37	0.38	0.38	0.36	0.35
France	0.32	0.39	0.36	0.36	0.36	0.35	0.33	0.34	0.34	0.35	0.34	0.33	0.35	0.35	0.35	0.34	0.34	0.33	0.31	0.34
China	0.17	0.20	0.23	0.27	0.30	0.31	0.29	0.32	0.31	0.32	0.34	0.34	0.39	0.40	0.42	0.46	0.47	0.49	0.45	0.34
Norway	0.31	0.16	0.35	0.32	0.33	0.33	0.34	0.34	0.35	0.34	0.35	0.33	0.35	0.36	0.37	0.37	0.39	0.38	0.37	0.34
United Kingdom	0.32	0.40	0.37	0.37	0.38	0.37	0.35	0.34	0.33	0.33	0.32	0.30	0.32	0.32	0.32	0.31	0.31	0.31	0.30	0.33

Country Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Ukraine	0.53	0.36	0.37	0.41	0.38	0.36	0.30	0.30	0.29	0.28	0.26	0.23	0.26	0.26	0.29	0.29	0.31	0.34	0.34	0.32
Russian Federation	0.40	0.46	0.42	0.38	0.35	0.32	0.30	0.29	0.29	0.29	0.27	0.25	0.26	0.27	0.29	0.29	0.29	0.30	0.29	0.32
Estonia	0.21	0.27	0.26	0.28	0.28	0.31	0.29	0.33	0.35	0.38	0.40	0.36	0.35	0.35	0.33	0.31	0.32	0.32	0.32	0.32
Portugal	0.16	0.21	0.21	0.22	0.23	0.27	0.27	0.34	0.34	0.35	0.35	0.33	0.34	0.35	0.35	0.35	0.36	0.37	0.37	0.30
Croatia	0.26	0.34	0.33	0.36	0.35	0.32	0.30	0.32	0.31	0.29	0.29	0.25	0.27	0.26	0.27	0.27	0.28	0.30	0.29	0.30
Poland	0.25	0.31	0.32	0.35	0.35	0.34	0.28	0.29	0.26	0.26	0.24	0.24	0.26	0.28	0.29	0.29	0.31	0.32	0.30	0.29
Hungary	0.26	0.31	0.30	0.30	0.32	0.31	0.27	0.30	0.28	0.27	0.28	0.26	0.28	0.29	0.28	0.26	0.28	0.31	0.30	0.29
Lithuania	0.21	0.27	0.25	0.30	0.31	0.32	0.27	0.33	0.31	0.30	0.29	0.24	0.27	0.29	0.28	0.26	0.27	0.26	0.26	0.28
Ireland	0.20	0.24	0.23	0.24	0.26	0.25	0.24	0.27	0.27	0.28	0.28	0.31	0.33	0.33	0.29	0.28	0.28	0.26	0.24	0.27
Tunisia	0.08	0.15	0.17	0.22	0.25	0.26	0.26	0.29	0.29	0.28	0.28	0.24	0.28	0.29	0.31	0.34	0.36	0.35	0.30	0.26
Spain	0.20	0.26	0.26	0.27	0.28	0.29	0.27	0.29	0.28	0.28	0.27	0.25	0.26	0.26	0.26	0.25	0.25	0.26	0.24	0.26
Serbia	0.02	0.04	0.03	0.05	0.05	0.05	0.35	0.35	0.36	0.36	0.36	0.37	0.36	0.37	0.38	0.37	0.37	0.36	0.34	0.26
Sri Lanka	0.26	0.30	0.30	0.25	0.10	0.43	0.31	0.20	0.29	0.37	0.23	0.13	0.34	0.28	0.32	0.20	0.19	0.21	0.12	0.25
Slovak Republic	0.23	0.27	0.26	0.27	0.26	0.25	0.22	0.24	0.22	0.24	0.24	0.23	0.25	0.26	0.27	0.25	0.27	0.26	0.25	0.25
Bulgaria	0.24	0.28	0.28	0.29	0.29	0.25	0.25	0.24	0.24	0.22	0.20	0.18	0.21	0.22	0.23	0.22	0.23	0.25	0.26	0.24
New Zealand	0.30	0.15	0.35	0.17	0.35	0.18	0.33	0.15	0.33	0.13	0.32	0.10	0.31	0.11	0.35	0.10	0.34	0.10	0.33	0.24
Luxembourg	0.01	0.01	0.28	0.26	0.27	0.25	0.26	0.26	0.27	0.28	0.30	0.24	0.26	0.27	0.26	0.25	0.26	0.24	0.24	0.23
Greece	0.16	0.10	0.20	0.17	0.25	0.25	0.23	0.18	0.16	0.16	0.24	0.22	0.26	0.26	0.28	0.27	0.29	0.30	0.29	0.23
Iran, Islamic Rep.	0.05	0.07	0.09	0.11	0.15	0.20	0.17	0.29	0.25	0.25	0.22	0.23	0.25	0.24	0.23	0.27	0.39	0.31	0.40	0.22
Italy	0.16	0.20	0.20	0.20	0.21	0.21	0.21	0.22	0.22	0.21	0.21	0.20	0.22	0.23	0.22	0.23	0.24	0.25	0.24	0.22
Moldova	0.35	0.26	0.33	0.29	0.34	0.26	0.25	0.23	0.18	0.16	0.13	0.12	0.12	0.12	0.12	0.14	0.12	0.12	0.11	0.20
Australia	0.08	0.39	0.11	0.37	0.13	0.40	0.11	0.39	0.09	0.38	0.22	0.06	0.21	0.08	0.20	0.08	0.19	0.09	0.17	0.20

Country Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Armenia	0.30	0.34	0.30	0.25	0.30	0.24	0.18	0.19	0.18	0.19	0.18	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.12	0.20
Latvia	0.15	0.19	0.14	0.14	0.16	0.16	0.15	0.19	0.18	0.19	0.23	0.19	0.20	0.20	0.21	0.18	0.20	0.20	0.19	0.18
Switzerland	0.07	0.09	0.10	0.39	0.12	0.12	0.09	0.35	0.08	0.07	0.07	0.38	0.06	0.07	0.42	0.07	0.40	0.07	0.38	0.18
Turkiye	0.11	0.14	0.16	0.19	0.19	0.19	0.18	0.19	0.20	0.19	0.18	0.16	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.18
Romania	0.14	0.17	0.16	0.16	0.17	0.16	0.17	0.20	0.21	0.23	0.20	0.17	0.18	0.17	0.19	0.17	0.17	0.16	0.15	0.17
Belarus	0.26	0.27	0.28	0.27	0.25	0.21	0.21	0.18	0.18	0.17	0.15	0.13	0.13	0.09	0.08	0.08	0.09	0.10	0.09	0.17
Malaysia	0.03	0.09	0.05	0.11	0.06	0.12	0.06	0.16	0.20	0.23	0.24	0.22	0.11	0.27	0.28	0.28	0.13	0.26	0.13	0.16
Georgia	0.20	0.21	0.20	0.24	0.25	0.22	0.15	0.15	0.16	0.10	0.10	0.08	0.10	0.12	0.14	0.15	0.14	0.15	0.14	0.16
India	0.12	0.14	0.16	0.18	0.18	0.18	0.16	0.17	0.16	0.16	0.15	0.13	0.14	0.15	0.15	0.15	0.15	0.17	0.12	0.15
Brazil	0.11	0.13	0.14	0.15	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.14	0.16	0.16	0.14	0.14	0.14	0.14	0.14	0.15
Hong Kong, China	0.08	0.12	0.12	0.12	0.14	0.13	0.14	0.13	0.14	0.15	0.15	0.15	0.16	0.17	0.16	0.16	0.17	0.17	0.17	0.14
North Macedonia	0.12	0.13	0.13	0.13	0.14	0.14	0.15	0.14	0.13	0.13	0.14	0.14	0.15	0.15	0.16	0.14	0.14	0.14	0.12	0.14
Cyprus	0.05	0.09	0.09	0.11	0.12	0.12	0.12	0.13	0.14	0.14	0.13	0.12	0.15	0.16	0.16	0.16	0.18	0.19	0.19	0.13
Malta	0.03	0.09	0.08	0.10	0.11	0.12	0.11	0.14	0.12	0.14	0.15	0.16	0.17	0.16	0.16	0.16	0.17	0.17	0.15	0.13
South Africa	0.11	0.07	0.13	0.15	0.14	0.15	0.12	0.13	0.12	0.11	0.11	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.13	0.12
Jordan	0.08	0.12	0.12	0.14	0.13	0.14	0.11	0.15	0.10	0.10	0.08	0.07	0.07	0.07	0.09	0.14	0.12	0.13	0.15	0.11
Egypt, Arab Rep.	0.05	0.06	0.07	0.09	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.09	0.11	0.12	0.13	0.13	0.13	0.14	0.15	0.10
Montenegro	0.00	0.00	0.05	0.07	0.06	0.07	0.12	0.06	0.05	0.08	0.13	0.09	0.15	0.15	0.17	0.16	0.18	0.17	0.17	0.10
Argentina	0.09	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.09	0.10
Thailand	0.05	0.05	0.07	0.06	0.08	0.08	0.07	0.07	0.08	0.05	0.09	0.04	0.10	0.11	0.11	0.13	0.16	0.18	0.17	0.09
Bosnia & Herzegovina	0.03	0.03	0.06	0.08	0.09	0.10	0.07	0.09	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10	0.13	0.12	0.11	0.08
Chile	0.04	0.06	0.06	0.07	0.07	0.07	0.09	0.10	0.09	0.08	0.08	0.07	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.08

Country Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Morocco	0.08	0.08	0.09	0.06	0.05	0.11	0.06	0.07	0.05	0.11	0.07	0.07	0.05	0.09	0.05	0.11	0.08	0.09	0.10	0.08
Cuba	0.09	0.10	0.10	0.10	0.10	0.10	0.07	0.08	0.09	0.08	0.06	0.05	0.06	0.06	0.06	0.05	0.05	0.06	0.05	0.07
Mongolia	0.10	0.12	0.15	0.11	0.08	0.09	0.07	0.06	0.08	0.08	0.04	0.03	0.07	0.06	0.05	0.05	0.06	0.04	0.04	0.07
Azerbaijan	0.09	0.12	0.13	0.14	0.10	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.04	0.04	0.05	0.05	0.10	0.07
Pakistan	0.03	0.04	0.03	0.04	0.08	0.06	0.09	0.06	0.09	0.06	0.08	0.05	0.08	0.06	0.08	0.07	0.10	0.09	0.11	0.07
Uzbekistan	0.14	0.14	0.14	0.09	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.07
Mexico	0.04	0.06	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06
Uruguay	0.02	0.06	0.04	0.04	0.04	0.06	0.05	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.06
Lebanon	0.05	0.05	0.06	0.07	0.07	0.08	0.06	0.06	0.05	0.04	0.04	0.03	0.05	0.05	0.06	0.06	0.06	0.08	0.09	0.06
Kazakhstan	0.07	0.08	0.07	0.07	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.03	0.06	0.07	0.06	0.06	0.06	0.06	0.05	0.06
Nepal	0.02	0.03	0.06	0.06	0.08	0.09	0.07	0.06	0.07	0.06	0.04	0.03	0.04	0.04	0.04	0.05	0.06	0.06	0.07	0.05
Algeria	0.03	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.05	0.05	0.12	0.07	0.07	0.05
Costa Rica	0.02	0.02	0.05	0.05	0.03	0.05	0.04	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.02	0.04
Colombia	0.02	0.02	0.03	0.03	0.03	0.04	0.03	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.04
Macao SAR, China	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.05	0.10	0.11	0.12	0.12	0.04
United Arab Emirates	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.01	0.05	0.13	0.14	0.02	0.16	0.15	0.04
Kenya	0.03	0.04	0.04	0.05	0.04	0.04	0.06	0.04	0.04	0.08	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Jamaica	0.03	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03
Kuwait	0.04	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.06	0.03	0.03	0.04	0.04	0.03	0.03
Mauritius	0.04	0.05	0.04	0.05	0.06	0.03	0.02	0.02	0.02	0.02	0.01	0.03	0.02	0.02	0.02	0.03	0.05	0.06	0.07	0.03
Zimbabwe	0.03	0.03	0.04	0.04	0.04	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03
Saudi Arabia	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.07	0.07	0.07	0.07	0.03	0.03	0.03	0.03	0.04	0.04	0.03

Country Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Vietnam	0.01	0.03	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.03	0.02	0.06	0.02	0.07	0.03	0.08	0.04	0.09	0.03
Ghana	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.03	0.02	0.05	0.02	0.02	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.03
Oman	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.03
Seychelles	0.03	0.04	0.07	0.05	0.04	0.03	0.03	0.03	0.02	0.03	0.02	0.01	0.02	0.01	0.03	0.03	0.02	0.02	0.01	0.03
Trinidad and Tobago	0.03	0.03	0.03	0.04	0.04	0.03	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.04	0.04	0.04	0.03
Barbados	0.03	0.03	0.04	0.05	0.03	0.04	0.03	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Samoa	0.04	0.04	0.03	0.03	0.03	0.07	0.02	0.02	0.02	0.02	0.01	0.00	0.01	0.03	0.03	0.02	0.02	0.03	0.02	0.03
Ecuador	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.03	0.03	0.03	0.04	0.05	0.01	0.02	0.03	0.05	0.05	0.02
Monaco	0.02	0.02	0.03	0.05	0.05	0.03	0.02	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Bangladesh	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.02
Brunei Darussalam	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.03	0.07	0.04	0.02
Albania	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
St. Kitts and Nevis	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.04	0.06	0.06	0.07	0.02
Namibia	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.04	0.02	0.02	0.02	0.04	0.03	0.02
Bahrain	0.01	0.01	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.02	0.02	0.02
Iraq	0.00	0.00	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.08	0.02
Panama	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02
Nigeria	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.02
Qatar	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.06	0.02	0.02	0.07	0.02	0.02
Indonesia	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.04	0.05	0.07	0.09	0.02
Philippines	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.04	0.02	0.02
Peru	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.01

Country Name	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
San Marino	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.01	0.02	0.03	0.04	0.04	0.03	0.01
Venezuela, RB	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.00	0.00	0.01	0.01
Bolivia	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Paraguay	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.01	0.02	0.02	0.02	0.01
Belize	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Nicaragua	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
El Salvador	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Antigua and Barbuda	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Guatemala	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Honduras	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Andorra	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
Bahamas, The	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dominican Republic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Angola	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00