# ESSAYS ON PATENT RIGHTS PROTECTION, TECHNOLOGICAL EFFORTS, AND EXPORTS

**Ph.D. Thesis**

By

**SIDHESWAR PANDA**

**DISCIPLINE OF ECONOMICS**

**INDIAN INSTITUTE OF TECHNOLOGY INDORE**

**AUGUST 2020**

# ESSAYS ON PATENT RIGHTS PROTECTION, TECHNOLOGICAL EFFORTS, AND EXPORTS

**A THESIS**

*Submitted in partial fulfillment of the*
*requirements for the award of the degree*
***of***
**DOCTOR OF PHILOSOPHY**

*by*

**SIDHESWAR PANDA**

**DISCIPLINE OF ECONOMICS**

**INDIAN INSTITUTE OF TECHNOLOGY INDORE**

**AUGUST 2020**

# INDIAN INSTITUTE OF TECHNOLOGY INDORE

## CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **ESSAYS ON PATENT RIGHTS PROTECTION, TECHNOLOGICAL EFFORTS, AND EXPORTS** 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 2015 to August 2020 under the supervision of Dr. Ruchi Shrma #1, Associate 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.

24 August 2020
**(SIDHESWAR PANDA)**

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

Ruchi Sharma 24 August 2020
**(Dr. RUCHI SHARMA)**

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**<NAME OF THE PhD STUDENT>** has successfully given his/her Ph.D. Oral Examination held on **<Date of PhD Oral Examination>**.

Signature of Chairperson (OEB)
Date: 11/02/2021

Signature of External Examiner
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Date: 11/2/2021

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Date: 11/02/2021

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# ACKNOWLEDGEMENTS

This dissertation would not have been possible without the support and encouragement of my committee, colleagues, friends, and family. First and foremost, the enormous depth of gratitude and indebtedness that I owe to my supervisor Dr. Ruchi Sharma, Associate Professor, School of Humanities and Social Sciences (HSS), Indian Institute of Technology Indore for her united guidance, intellectual supports, valuable time, sharing the ideas and discussions, continuous encouragement, and sense of motivation in the completion of my PhD works. I feel fortunate that I had an opportunity to learn a lot from her, and I could complete the dissertation successfully.

I would like to extend my sincere gratitude to Prof. Walter G. Park, American University, USA for his intellectual supports and valuable suggestions on my PhD work that enabled me to complete my dissertation in time with utmost satisfaction. His enthusiasm for research has always motivated me to conduct excellent research.

I am further indebted to PSPC members Dr. Pritee Sharma and Dr. Swadesh Kumar Sahoo for their valuable suggestions and constructive comments throughout my research. I extend my thanks to the head of the department, DPGC Convener of HSS for their academic support. I would also like to acknowledge the institute and MHRD, Govt. Of India for the financial support during the tenure of my work.

My special words of thanks to Dr. Amarjeet Nayak, Dr. Satya narayan Mishra, Dr. Bharath Kumar, Dr. Debasis Nayak, Dr. Sri Gobinda Patra, and Dr. Prashant Kodgire for their valuable suggestions and supports.

I am grateful to RIS, New Delhi, for providing data for my PhD work. Expressly, my sincere thanks to Dr. Durairaj Kumarasamy for his valuable time and motivations.

My research has greatly benefited from Globelics –The Global Research Network Conference and Doctoral Academy, RIS-EXIM Bank Summar School, and GIAN workshops. My sincere thanks to Prof. Keun Lee, Prof. Sachin Chaturvedi, Prof. B. N. Goldar, Prof J. E. Cassiolato, Prof. Helena M. Lastres, Prof. Mario Scerri, Prof. Attila Havas, Prof. Rasigan Maharajh, for the insights and encouragements.

I express my warm gratitude to Prof. N. Chandrasekhar Rao, Prof. Arup Mitra, Prof. Pravakar Sahoo, Dr. Pratap C. Mohanty, Dr. Shesadri Banerjee, and Dr. Subash Sasidharan for their valuable suggestions and motivations.

I am indebted to Prof. Asit Ranjan Mohanty, Dr. Dinabandhu Sethi, Dr. Balakrishna Padhi, Lalhriat Chiani, Shri Anirudha Barik, and Shri Purnendu P Panda for their help and suggestions.

My sincere words of thanks to Mrs. Swati Biswal, Shri Pradeep K. Sahoo, Shri Debashis Giri, Shri Narayan Giri, Dr. Yashobanta Parida, Shri Jagadish P. Sahoo, Dr. Ranjan K. Mohanty, Dr. Devi P. Dash, Dr. Suresh K. Patra, Shri Ajit Rana, Shri Chandan K. Das, Dr. Bijaya K. Sethi, Shri Ummalla Mallesh, Tapasi Mohanty, Lopamudra Sahoo, Dr. Kalandi C. Pradhan and Dr. Sivananda Nayak for their love and motivation.

I have been blessed with having pleasant friends and colleagues around me. Especially, I tender my heartfelt thanks to Manu Jose, Debjit Misra, Subhmit Chakroborthy, Shadab Danish, Aparna Sharma, Md Danish, Madan Dhanora, Ishfaq Majeed, Aakriti Jain, Qayoom Khachoo, Sanjaya K. Lenka, Arushi Jain, Avi Vani, Busra Parveen, Vivek Yadav, Debashis Panda, Arun Bairwa, Shaifali Arora, Shanmuga Priya, Ankit Tiwari, Vinod S. Parashar, Rajesh Barik, and Prasanta Patri for their help in numerous ways.

I owe my deepest gratitude towards Ma. Nivedita Bhide, Ma. Bhanudas Dhakras, Ma. Kishor Tokekar, Ma. Premananda Piri, Ma. Sudhakar

Ramdurg, Ma. Shyamala Ramdurg, Ma. Ravi Naidu, Ma. Laxinarayan Panigrahi, Ma. Manas Bhattacharjee, Ma. Rachana Jani, Ma. Alaka G. Joshi, Ma. Manoj Das, Ma. Atul Ghabne, and others for their blessings, affections and love towards me. They are my inspiration to be a good human being.

Finally, my family has been a great source of support and encouragement. I owe eternal gratitude to my (late) parents for guiding me to the path of righteousness; for encouraging me to do higher study; for their blessing and love. I dearly miss you, Maa and Bapa, but I know your blessings are my fortune!

I would also like to pay high regard to my elder brothers for their blessing, goodwill, affection and keeping faith in me that I would do well in it. Such a long and successful journey would not have been possible without their confidence in my abilities to seek my destiny.

A special mention of thanks to my Kaka, my sisters, sister-in-laws, Dibyadipti, and Ratikanta for their love, goodwill, affection, and constant supports.

I am quite sure that all my words cannot completely express my emotion and gratitude to all those who have helped me in carrying out such a long journey.

Last but not least, I owe my head to the Almighty for his blessing and an unseen helping hand.

**SIDHESWAR PANDA**

**Dedicated to my (late) beloved parents and family for guiding me to the path of righteousness**

# SYNOPSIS

## Introduction

From Solow growth model to endogenous growth models, technology is at the heart of the economic development process. Furthermore, lessons from trade liberalization show that export orientation rather than infant industry protection should be the strategy for economic development. Developing economies motivated to become internationally competitive make extensive efforts to raise their export performance. Among such efforts, the broad concern of this dissertation is to examine the impact of patent rights (PRs) on innovation of a country and their contribution to exports. This dissertation proposes an incremental perspective concerning the channel through which countries gain from strengthening PRs. Through a development of deeper understanding of patent rights, innovation and exports, we aim to augment the understanding about the role of patent rights in innovation and its effectiveness in exporting across countries at both aggregated and disaggregated levels.

Lall (2003) has argued that developing countries' innovation activity is a process of learning to use imported technologies efficiently rather than to innovate on the technological frontier and its exporters face many problems in order to enter into the global market and access information, due to higher production cost. Hence, they are not directly involved in innovating and pushing the frontiers of knowledge. Instead, such economies acquire, adapt, and improve the existing technologies from the international technology market. Accordingly, the existing evidence on the role of innovation in developing countries exports is mixed. Shin et al. (2016) argue that within the developing countries the technology levels vary leading to a complex picture. For example, developing countries' innovation is based on adaptive R&D for high-technology products. Evidently, countries export such products if these are not protected in the international markets. Moreover, for some developing countries innovation levels have evolved up the technology ladder in a few sectors to produce and export patented product that may be in the first stage of product cycle development.

Most of the existing studies highlight the developed countries' perspective, with developing countries as a net consumer of new products. The impact of stronger PRs protection varies across countries, depending on the ability to innovate. The existing studies do not examine the influence of the exporting countries' PRs protection on their innovation. According to the promotional channel of gains from PRs, strong protection is expected to stimulate domestic innovation. The impact of a source country's PRs on its export through the stimulation of innovation remains unexplored in the literature. Therefore, in this dissertation, we are interested to study the relationship between PRs and exports conditioned by innovation in the source country. To capture the innovation by countries, existing studies use either input based measures like R&D expenditure or output based proxies like patents. Lall (2003) provides an index of technology effort, based on national technological activity which is derived from two variables, such as R&D financed by productive enterprises and the number of patents taken out internationally. Shin et al. (2016) measure a country's level of technology by its patents. As patents do not represent the complete innovation value such measures *cannot* capture the extent of technological efforts made by developing countries. Within the developing countries, as mentioned earlier, different variants of 'effort' may exist. Hence, to measure countries' innovation activity, in this dissertation, we propose to construct a technological effort (TE) index based on the input and output indicators of innovation and ask the following questions:

1. Do countries' patent rights support technological efforts?
2. Do technological efforts contribute to the exports?
3. Do countries' technological efforts influence export margins—extensive and intensive margins of exports?

**Literature Review**

Innovation plays a major role in determining exports, and hence, economic growth of a country by strengthening domestic industries. Proponents of patent policy reforms argue that PRs affect innovation and stimulate economic growth. Earlier studies, however, seem to show that the impact of strong PRs on innovation and the economic growth of developing countries is predominantly negative. Considering the potential impact of PRs on innovation in advanced countries, studies argue that the returns to innovation are increased by strong PRs protection (Allred and Park, 2007a). Extant literature explores the promotion channel connecting patent right and innovation finds mixed results. Chen and Puttitanun (2005) confirm that U-shape relationship between innovation and PRs protection of a developing country. Interestingly, Allred and Park (2007) examine the effects of patent rights on different aspects of innovation activities, namely R&D and patenting. They find that the impact of PRs on innovative activity is very complex, and subsequently depends on the initial level of PRs strength, and it differs by countries' level of economic development. Studies like Kim et al. (2012) and Sweet and Maggio (2015) suggest that PRs' impact may differ by the development level of the country, where developed countries tend to benefit more with the strong enforcement of the PRs norms. Further, they argue that developing countries do not enjoy the benefits of global PRs standardization. Studies also argue that optimum PRs' protection is stage-dependent. While countries implement weak PRs protection in the early stages of economic development to encourage imitation, in the later stages of development, they implement strong PRs protection to stimulate innovation. Studies also suggest that the impact of countries' PRs on innovation depends upon countries' technological efforts.

Studies underscore that innovation and new technology adoption enable firms to enter foreign markets and enhance their export performances in developed countries. In the context of developing countries, studies find mixed evidence regarding the role of technology in explaining trade performance.

At present the innovativeness of developing countries may have reached a stage where it can be positively affected by strong PRs. Ongoing studies explore the impact of PRs either on economic growth or on innovativeness through R&D expenditure and patenting. It is not evident in these studies how the changes in innovativeness translate into economic growth. In this dissertation, we study the impact of PRs on the technological efforts of a country and their contribution to high-technology exports. We combine the TEs made by countries and their contribution to high-technology exports in order to explain a mechanism through which strong PRs contribute to economic growth, as such a channel remains unexplored in the current literature.

Furthermore, recent studies in international trade explore the extensive and intensive margins of trade. The extensive margin is defined as a change in the number of trading partners or number of products traded. It captures the increase in variety of exports and shows the changes in tastes of the importer, as consumers abroad seek to try new goods. The intensive margin is defined as the change in volume of trade among two countries. It captures how exports are spread across varieties. As we discussed earlier, there are variations among the developing countries in terms of technology efforts and its influence on export growth. Hence, we are interested to understand the patterns of bilateral trade and the product dimension cross countries at disaggregated level. Studies examine the impact of several trade policies on the margins of trade, namely, trade liberalisation, membership in multilateral organisation, hosting mega-events (namely, the Olympics and the World Cup), and PRs on bilateral trade flows. However, these studies do not take into consideration the TEs of the country. Therefore, we explore the impact of TEs on bilateral exports by decomposing total exports into two margins of trade, utilising disaggregated products level export data.

### Research Objectives

Based on above discussion, the objectives of the dissertation are:

1. To examine the impact of source countries' patent rights protection on technological efforts.
2. To investigate the impact of source countries' technological efforts on exports.
3. To study the impact of source countries' technological efforts on bilateral exports along with export margins—extensive and intensive export margins.

### Data and Methods

#### Data

We undertake three studies to address the above-mentioned objectives. As the main objective is to focus on the PRs on innovation and then exports, the first essay undertakes extensive review of literature. The review is further strengthened by meta-regression analysis to understand the sensitivity of results of empirical studies to data, period of study and most importantly to the level of economic development of sample countries. To investigate the relationship between PRs and innovation, we went through 14 empirical studies containing 145 estimates undertaken during 1995-2019. The second part of the study focuses on the impact of innovation on exports based on 27 empirical studies containing 249 estimates during 1996-2019.

For the first and second objectives, this dissertation utilises panel data for 67 countries during 1996-2014. We estimate the relationship between PRs, TEs and exports by subgroups of high-income and middle-income countries based on the World Bank (2016) classification of economies. To conduct empirical investigation, important sources of data are World Development Indicators (WDI), Park (2008), UN Comtrade, World Integrated Trade Solution (WITS), World Intellectual Property Organization (WIPO).

For the third objective of the dissertation, we utilise product level exports data to analyse the relationship between technological efforts and export margins— extensive and intensive margins for 56 countries during 1996-2014. Export data are extracted at the Harmonised System (HS) 6-digit level of disaggregation from UN COMTRADE. Following Delgado, Kyle and McGahan (2013) classification, we take high PRs sensitive products that are classified in the Standard International Trade Classification (SITC), then we made concordance between SITC and HS.

**Methodology**

We utilise meta-regression analysis (MRA) to tests whether the empirical findings are sensitive to various measures employed, and hence, identifying possible policy implications across countries. MRA harmonizes empirical survey results, combining the findings of various studies that use different data and methodologies, and presents a clear and descriptive result.

In the second essay, we use panel data analysis to quantify the effect of PRs protection on technology effort and in turn its influence on high-technology exports. To measure countries technological efforts, we construct an index by utilising principal component analysis (PCA), including both input and output indicators of innovation. The technological efforts index ranges from 0 to 5.37 where higher values indicate intensive innovation activity. The average of TE index of high-income and middle-income countries are 1.9 and 0.35 and maximum value of TE index are 5.37 and 1.99 respectively. In the estimations, both fixed effect (FE) and random effect (RE) regression techniques are applied to estimate the coefficients. Finally, the choice between FE and RE technique is based on the Hausman specification test.

In a gravity model (GM) setting, we examine the impact of technological efforts on exports along with margins of trade, to understand the bilateral export flows across countries. We develop the model with the key variables, namely, exporter TEs, importers PRs, and their interactions. We address major challenges and solution, namely, multilateral resistances (MRs) term, zero trade flows, heteroskedasticity of exports data, endogeneity issues and bilateral trade costs, in order to obtain consistent estimates. To build the margins of exports, we apply the count method to construct the export margins. We implement the Poisson Pseudo-Maximum Likelihood (PPML) estimation technique as an appropriate methodology to estimate the impact of technological efforts on bilateral exports along with the extensive and intensive margin of trade.

**Empirical Results**

The synthesis of narrative reviews and meta-regression analysis in chapter 2 reveals that innovation determines exports success across countries. By the form of countries, we find strong evidence which indicates that developed countries' domestic innovation enhances their exports; notwithstanding, for developing countries, innovation does not contribute to their exports.

The results of the second essay are given in Tables 1 and 2 which present the empirical results of the relationship between PRs & TEs, and TEs & exports respectively. In Tables 1 and 2, "S" stands for source country and "D" stands for destination countries. We present results for all countries, and by subgroups: high-income (HI) and middle-income (MI) countries. We report both fixed effect (FE) and random effect (RE) estimates, though our discussion is based on the model selected as per the Hausman test. Column 1 presents the variables names. Columns 2 and 3 present two models, namely regression with key variables and regression including control variables with FE estimates and next two column for RE estimates for all countries, HI and MI countries respectively. These results show that a source country's PRs protection positively stimulates its technological efforts in both high income and middle-income countries. Furthermore, the technology efforts of a source country positively influence the high technology exports of high-income countries. But the empirical result indicates that technology efforts do not contribute to the high-tech exports of middle-income countries. A probable reason is that within developing countries the technology efforts vary, and some developing countries may be engaged in adaptive R&D for high-technology products that are in the second or third stage of product cycle development. The destination countries' PRs index is a positively significant determinant of source countries' incentive to export, which highlights that both high- and middle-income countries would export more to countries with a strong PRs protection, controlling for other factors. An interesting finding is that the interaction coefficient of source countries' TE and destination countries' PRs is negatively related to exports for high income countries whereas for middle income countries, it is insignificant. For high-income countries, this is due to PRs having a net market power effect for technology intensive products, which moderates the market expansion effect of foreign patent rights. For middle income countries, the technological efforts are still relatively low so that the technological intensity of their high-tech products does not condition the response of their exports to foreign patent regimes.

The results of the third essay are given in Table 3 where "i" stands for source country and "j" for destination countries. We tabulate the impact of TEs on exports utilising disaggregated exports data for full sample. First, we discuss the empirical results for total exports in panel A and exports margins in panel B. We utilise four econometric models with year fixed-effects and results are given in the Columns 1-4 for different panels of Table 3. Model (1) is an OLS regression model with exporters and importers time fixed-effects adjusted for MR terms (Column 2). Model (2) contains fixed effects (FEs) model with dyadic (pair) fixed-effects to account for pair-specific time invariant characteristics (Column 3). Model (3) emerges when we utilise our preferred model, the PPML with only importer and exporter time fixed-effects (Column 4). The final model, Model (4) with country's dyadic fixed-effects, the Poisson fixed-effects model (Column 5). Model (4) is our chosen model specification for the discussion. In the next four columns, Models 1-4 are presented for exports margins estimates respectively.

We find strong evidence that countries' TEs contribute to bilateral exports along with trade margins. Countries technological efforts increases the likelihood that countries become motivated to export high technology products along with product variety and export volumes. Importing countries PRs protection stimulates bilateral exports along with product variety, however, it does not contribute to exports' volume. This result indicates that countries' patent rights enhance quality of imports rather quantity/volume of exports. We have also examined the interaction between source countries' TEs and the destination countries' PRs environment. The fact that the interaction effect has a negative influence on exports in high-income countries suggests that stronger destination PRs enable source country firms to exploit market power, if they possess greater technological capacity.

Based on the level of economic development, this study reveals strong evidence that technological level augments bilateral exports only along the extensive margins. It implies that technological capacity plays a significant role for countries' product diversification and exports quality across income groups.

## Table 1: Results of PRs and technology effort

| Dependent Variable: Tech Efforts Index | All countries | | | | High Income | | | | Middle Income | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FE | | RE | | FE | | RE | | FE | | RE | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| PR_S t-1 | 0.05 | 0.05 | 0.08* | 0.10* | 0.32** | 0.13 | 0.31** | 0.28** | 0.08** | 0.09** | 0.09*** | 0.09*** |
| | (0.05) | (0.06) | (0.05) | (0.06) | (0.15) | (0.15) | (0.13) | (0.13) | (.03) | (0.04) | (0.03) | (0.01) |
| TII_S t-1 | 2.99*** | 2.27*** | 3.36*** | 3.13*** | 3.14*** | 2.11*** | 3.36*** | 3.08*** | 1.2*** | 1.19** | 1.15*** | 1.35*** |
| | (0.38) | (0.46) | (0.3) | (0.35) | (0.57) | (0.65) | (0.50) | (0.55) | (0.3) | (0.5) | (0.29) | (0.39) |
| Size_S | | (0.0008) | | -<br>0.01*** | | 0.01 | | -0.02 | | 0.01* | | -0.006 |
| | | (0.01) | | (0.007) | | (0.02) | | (0.01) | | (.008) | | 0.004 |
| Edn_S t-1 | | -0.0009 | | -0.001 | | -0.0004 | | 0.0002 | | 0.0007 | | 0.0003 |
| | | (0.002) | | (0.002) | | (0.003) | | (0.003) | | (0.001) | | (0 .001) |
| Capital_S | | -0.01 | | -0.01** | | 0.01 | | 0.005 | | 0.002 | | -0.007 |
| | | (0.008) | | (.008) | | (0 .01) | | (0.01) | | (0 .008) | | (.006) |
| OPN_S t-1 | | 0.59*** | | -0.02 | | 1.13*** | | 0.16 | | 0.01 | | -0.01 |
| | | (0.18) | | (0.07) | | (0.35) | | (0.24) | | 0.16 | | (0.04) |
| Constant | -0.52** | -0.23 | -0.85 | 0.85 | 1.51*** | -1.96 | -1.63** | -0.51 | 0.29*** | -1.4 | 0.31*** | 0.2 |
| | (0.20) | (0.89) | (0.19) | (0.65) | (.54) | (1.92) | (0.51) | (1.58) | (0.11) | (0 .6) | (0.11) | (0.41) |
| Hausman test | 10.02*** | 26.31*** | | | 0.89 | 22.99*** | | | 0.58 | 67.1*** | | |
| | (0.00) | (0.00) | | | (0.64) | (0.00) | | | (0.7) | (0.00) | | |
| R2 | 0.34 | 0.41 | 0.34 | 0.36 | 0.40 | 0.47 | 0.40 | 0.42 | 0.35 | 0.38 | 0.35 | 0.31 |
| Observation | 252 | 229 | 252 | 229 | 140 | 136 | 140 | 136 | 112 | 93 | 112 | 93 |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

## Table 2: Results of the TEs and export

| Dependent Variable: Exports | All countries | | | | High Income | | | | Middle Income | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FE | | RE | | FE | | RE | | FE | | RE | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| TE_S t-1 | 11.00** | 10.02* | 15.44*** | 13.89*** | 20.69*** | 18.21** | 27.80*** | 24.35*** | 14.12 | 14.5 | 15.546 | 15.82 |
| | (5.71) | (5.99) | (5.49) | (5.71) | (8.17) | (8.63) | (7.89) | (8.27) | (18.13) | (19.33) | (18.07) | (18.59) |
| PR_D t-1 | 2.99** | 3.21** | 3.47*** | 3.71*** | 7.23*** | 6.40** | 7.90*** | 7.41*** | 4.45* | 4.51* | 5.05** | 5.02** |
| | (1.42) | (1.51) | (1.4) | (1.47) | (2.89) | (3.10) | (2.92) | (3.03) | (2.63) | (2.8) | (2.62) | (2.75) |
| TE t-1*PR_D t-1 | -2.85** | -2.43* | -3.75*** | -3.20*** | -5.12*** | -4.36** | -6.57*** | -5.6*** | -3.71 | -3.8 | -4.07 | -4.17 |
| | (1.30) | (1.37) | (1.26) | (1.32) | (1.88) | (2.01) | (1.83) | (1.94) | (4.77) | (5.07) | (4.70) | (4.84) |
| GDP_D t-1 | | 0.25 | 0.05 | 0 .33 | | 0 .35 | | 0.44 | | -0.02 | | .01 |
| | | (0.43) | | (.43) | | (0 .62) | | (0.61) | | (0.78) | | (0.76) |
| OPN_D t-1 | | -3.31 | | -4.05 | | -2.49 | | -3.27 | | -.60 | | -.65 |
| | | (3.16) | | (3.02) | | (6.8) | | (6.23) | | (4.27) | | (4.06) |
| EXR_S t-1 | | -0.0004 | | -0.0004 | | 0.003 | | -0.002 | | -.0003 | | -.0003 |
| | | (0.0007) | | (.0006) | | (0.01) | | (0.004) | | (0.0007) | | (0.0007) |
| Constant | 3.63 | 3.99 | 0.61 | 1.29 | -12.51 | -9.41 | -17.14 | -14.25 | -2.64 | -2.08 | -5.24 | -4.74 |
| | (5.75) | (6.26) | (5.86) | 6.31 | (12.14) | (13.27) | (12.29) | (13.15) | (9.24) | (11.35) | (9.6) | (11.26) |
| Hausman test | 8.85** | 5.96 | | | 2.59 | 6.46 | | | 6.56 | 0.52 | | |
| | (0.03) | (0.42) | | | (0.46) | (0.37) | | | (0.36) | (0.99) | | |
| R2 | 0.04 | 0.05 | 0.05 | 0.06 | 0.04 | 0.05 | 0.04 | 0.05 | 0.06 | 0.05 | 0.04 | 0.06 |
| Observations | 259 | 232 | 259 | 232 | 146 | 122 | 146 | 122 | 113 | 110 | 113 | 110 |

Note: Numbers in parentheses are standard errors. *, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

## Table 3: Empirical results of TEs and exports margins – Full sample

| | Panel A | | | | Panel B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Exports | | | | Extensive Margins | | | | Intensive Margins | | | |
| VARIABLES | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| TEi | 0.949*** | 0.390*** | 0.237*** | 0.086*** | 0.692*** | 0.388*** | 0.599*** | 0.151*** | 0.751*** | 0.006 | 0.135*** | 0.045*** |
| | (0.108) | (0.036) | (0.013) | (0.010) | (0.032) | (0.016) | (0.053) | (0.012) | (0.086) | (0.032) | (0.011) | (0.011) |
| IPRj | -1.216 | 0.244*** | -0.352*** | 0.040*** | -1.216* | 0.273*** | -0.998*** | 0.088*** | 0.006 | -0.028* | -0.054 | 0.008 |
| | (1.387) | (0.018) | (0.072) | (0.006) | (0.662) | (0.008) | (0.114) | (0.007) | (1.100) | (0.016) | (0.068) | (0.006) |
| IPR*TE | -0.043*** | -0.086*** | -0.029*** | -0.025*** | -0.086*** | -0.104*** | -0.052*** | -0.045*** | 0.043*** | 0.017** | -0.012*** | -0.012*** |
| | (0.007) | (0.009) | (0.001) | (0.003) | (0.003) | (0.004) | (0.001) | (0.003) | (0.006) | (0.008) | (0.001) | (0.003) |
| LGDPi | 1.470*** | 0.923*** | 0.229*** | 0.220*** | 0.752*** | 0.411*** | 0.533*** | 0.231*** | 0.683*** | 0.507*** | 0.199*** | 0.210*** |
| | (0.053) | (0.023) | (0.014) | (0.006) | (0.018) | (0.010) | (0.062) | (0.007) | (0.042) | (0.021) | (0.011) | (0.006) |
| LGDPj | 1.599*** | 0.793*** | 0.310*** | 0.086*** | 1.022*** | 0.266*** | 0.557*** | 0.065*** | 0.574 | 0.525*** | 0.169*** | 0.099*** |
| | (0.593) | (0.023) | (0.033) | (0.005) | (0.283) | (0.010) | (0.047) | (0.006) | (0.470) | (0.021) | (0.031) | (0.006) |
| LDistance | -1.525*** | | -0.162*** | | -0.750*** | | -0.188*** | | -0.780*** | | -0.141*** | |
| | (0.011) | | (0.002) | | (0.005) | | (0.002) | | (0.008) | | (0.002) | |
| COMLAN | 0.672*** | | 0.095*** | | 0.390*** | | 0.122*** | | 0.289*** | | 0.074*** | |
| | (0.027) | | (0.004) | | (0.013) | | (0.005) | | (0.021) | | (0.004) | |
| CONTIG | -0.300*** | | -0.099*** | | -0.331*** | | -0.152*** | | 0.026 | | -0.056*** | |
| | (0.036) | | (0.005) | | (0.017) | | (0.007) | | (0.029) | | (0.005) | |
| COLONY | 0.691*** | | 0.071*** | | 0.469*** | | 0.108*** | | 0.220*** | | 0.039*** | |
| | (0.037) | | (0.005) | | (0.018) | | (0.007) | | (0.029) | | (0.005) | |
| Constant | -53.183*** | -37.524*** | -9.251*** | -6.419*** | -30.757*** | -15.254*** | -22.243*** | -7.038*** | -22.447*** | -22.075*** | -6.753*** | -7.037*** |
| | (9.960) | (0.801) | (0.710) | (0.221) | (4.734) | (0.355) | (1.942) | (0.246) | (7.893) | (0.718) | (0.635) | (0.230) |
| Observations | 49,195 | 49,195 | 58,520 | 58,520 | 49,323 | 49,323 | 53,222 | 56,677 | 49,195 | 49,195 | 58,520 | 58,520 |
| R-squared | 0.857 | 0.871 | 0.886 | 0.819 | 0.853 | 0.868 | 0.804 | 0.807 | 0.759 | 0.768 | 0.850 | 0.782 |
| Year FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Exporters FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Importers FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Pair FE | | yes | | yes | | yes | | yes | | yes | | yes |

Numbers in parentheses are standard errors. *, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

**Policy Implication of the dissertation**

Based on our results, it has been suggested that policymakers of middle-income countries need to undertake awareness programs for exporters about PRs in other countries. These countries may also support exporters in marketing of the products, brand creation through various schemes including participation in international trade fairs. Initiatives to reduce the cost of exporters for patenting in different countries will also help exporters to increase the intensive margins. Furthermore, MI as importers of patent-sensitive products from high-income countries, need to be watchful to ensure that market power enjoyed by the HI countries' exporters is not abused.

**Contribution of the dissertation**

This dissertation contributes to the existing literature on PRs, technology, and trade in the following ways. First, we apply PCA to construct the technology effort index including both input and output indicator of innovation. Second, this study highlights an incremental perspective on an existing channel through which countries gain from PRs, as it influences the technology effort of countries that further stimulates their exports. Third, we approach the problem from the source country's perspective in order to introduce variations in terms of host country factors. Since developing countries have implemented patent policy changes to comply with TRIPs, a study that focuses on such economies is essential. Four, we contribute to the existing literature by examining the role of TEs on the bilateral exports along with margins of trade— extensive and intensive margins. Lastly, we have evaluated the change of bilateral exports based on countries' level of economic and technological development exploring the variation among countries in terms of income levels and in terms of technological efforts.

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6. Impact of Technological Efforts on Extensive and Intensive Margins of Trade, 2021. [Co-authors: Ruchi Sharma and Walter G Park]

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## ACRONYMS

| | |
|---|---|
| FAT | Funnel Asymmetric Test |
| FDI | Foreign Direct Investment |
| FE | Fixed Effect |
| GATT | General Agreement on Tariff and Trade |
| GDP | Gross Domestic Product |
| GNI | Gross National Income |
| GM | Gravity Model |
| HI | High-Income |
| HS | Harmonised System |
| IP | Intellectual property |
| IPR | Intellectual Property Rights |
| LP | Labour Productivity |
| MI | Middle-Income |
| MR | Multilateral Resistance |
| MRA | Meta-Regression Analysis |
| OECD | Organization for Economic Co-operation and Development |
| OLS | Ordinary Least Squares |
| PCA | Principal Component Analysis |
| PPML | Poisson Pseudo-Maximum Likelihood |
| PRs | Patent Rights |
| RE | Random Effect |
| REML | Random Effect Maximum Likelihood |
| R&D | Research and Development |

| | |
|---|---|
| SE | Standard Error |
| SITC | Standard International Trade Classification |
| SMEs | Small and Medium-sized Enterprises |
| TEs | Technological Efforts |
| TII | Technological Infrastructure Index |
| TRIPs | Trade-Related Intellectual Property Rights |
| UN Comtrade | United Nations Commodity Trade |
| WB | World Bank |
| WDI | World Development Indicator |
| WIPO | World Intellectual Property Organization |
| WITS | World Integrated Trade Solution |
| WLS | Weight Least Square |
| WTO | World Trade Organization |

# Chapter 1
# Introduction

## 1. The Context

The broad concern of this dissertation is to examine the impact of patent rights (PRs) protection on technological efforts of a country and their contribution to high-technology exports. This dissertation proposes an incremental perspective concerning the channel through which countries gain from strengthening PRs. Through the development of a deeper understanding of patent rights, technological efforts and exports, we aim to augment the role of patent rights in technological efforts and its effectiveness in exporting across countries at both aggregated and disaggregated levels.

### 1.1 Intellectual Property Rights (IPRs)

Intellectual property (IP) refers to creations of the mind, namely, inventions, literary and artistic works, and symbols, names, images, and designs used in commerce (World Intellectual Property Organization (WIPO), 2005). Intellectual property rights (IPRs), such as patents, copyrights and neighboring rights, trademarks, industrial designs, trade secrets, and geographical indications are legal and institutional devices to protect creations of the mind.[1] These rights over IP give right-holder an exclusive control over the commercial use of the creation for a limited time period.

The Agreement on Trade Related Intellectual Property Rights (TRIPs), is a product of the eighth round of the General Agreement on Tariff and Trade (GATT), held in Uruguay in 1986 of the trade negotiations. The TRIPs agreement is the first comprehensive and global set of rules covering IPRs protections (Braga, 1995). TRIPs are the norms that facilitate each country

[1]In this dissertation, IPRs refer to patents as other IPs raise different set of issues.

to protect their intellectual property with no harm from other nations or firms. Specifically, patent rights (PRs) have been internationalised with TRIPs that require developing countries to devise various IPRs as per the minimum standards, which is expected to bring benefits to the developing countries by creating an incentive structure essential for knowledge generation and diffusion, technology transfer and private investment flows (Braga, 1995; Fink and Maskus, 2005). Scholars view TRIPs as a response to the tremendous rise in the trade and investment flows between the countries – specifically the flow of patent-intensive products since the 1980's.

## 1.2 Patent Rights (PRs) and Innovation

The protection of patent rights (PRs), as a policy instrument to enhance innovation, provides temporary monopoly power to the innovator to appropriate returns from investments made in research and development (R&D). Research shows that the enforcement of PRs' protection plays a significant role in countries' innovation and technological development. The PRs of a country lead to the disclosure of information by the innovator and ensure the appropriability of R&D (Sharma and Saxena, 2012). Considering the potential impact of PRs on innovation in advanced countries, many studies argue that the returns to innovation are increased by strong PRs protection (Landes and Posner, 2003; Scotchmer, 2004; Allred and Park, 2007a).

Schumpeter (1912) defines innovation, as an introduction of a new product, a better method of production, a newer market, a novel source of raw materials and a better organisation technique. Further, innovation is categorised into technological innovation (such as product and process innovation) and non-technological innovation (such as market and organisation change). Innovation of a country not only depends on input innovation (R&D) but also output innovation (patent) that influence creation, adoption, adaptation, assimilation, diversification of technology, and technological learning of the country that further stimulates knowledge intensive products.

According to Lerner (2002), the prospect theory[2] may not apply to developing countries that are involved in adaptive technology, imitation, and follow-on-innovation. However, there is a positive impact of strong PRs on innovation through knowledge spillovers from patents and the appropriability effects of patent protection (Siebeck, 1990). Moreover, many studies suggest that the impact of countries' PRs on innovation depends upon countries' technological capabilities (Ginarte and Park, 1997; Schneider, 2005). The history of the patent system reveals that developed economies formulated PRs according to their strategic trade policy (Kaufer, 2012) as a significant policy tool that drives innovation by firms; and subsequently, the technological change of an economy. Arrow (1962) suggests that PRs play a major role in R&D activities. Griliches (1990) analyses the relevance of the patent data vis-à-vis R&D expenditure in capturing innovation activity and establishes R&D as an input in the knowledge production function that leads to an output in the form of a patent. Chu et al. (2014) argue that optimum PRs' protection is stage-dependent. While countries implement weak PRs protection in the early stages of economic development to encourage imitation, in the later stages of development, they implement strong PRs protection to stimulate innovation. The impact of PRs on innovation is ambiguous and conditional upon the level of development.

### 1.2.1 Technological Effort (TEs)

PRs protection is an institutional factor that supports the technological efforts of a country. Technological efforts (TEs) consist of a broad spectrum of production, design and research work with firms, and is

[2] Prospect theory argues that strong PRs provide innovators with incentives to commercialise and organise the market better for follow-on innovation (Kitch, 1977).

supported by a technological infrastructure. It is very difficult to measure TEs of a country properly. Many studies provide proxy to measure the TEs, that is, in the form of input measure as technical personnel available for technical tasks, or expenditures on formal R&D and output measures as innovation, patents and other indicators of technological success (Cohen and Levinthal, 1989; Griliches, 1990; Lall, 2000, 2003).

TEs of a country mostly depend on dynamism in technology development which also depend in term of national policies to improve factor markets and influence the incentive environment (Lall, 1992). Incentives, institutions, and factor market are the major determinants of technology development of a country (Lall, 1992 and 1998). Lall (2003) provides an index of technology effort, based on national technological activity which is derived from two variables, such as R&D financed by productive enterprises and the number of patents taken out internationally. Shin et al. (2016) measure a country's level of technology by its patents. Allred and Park (2007) suggest different channels by which the patent system may positively or negatively affect innovation and diffusion. Patents do not represent the complete value chain of innovation by missing the market dimension of innovation. Thus, there is a need to use a different indicator to capture or quantify technological activity. Having shown the existing literature on the measurement of technology is limited because the existing indicator captures either input or output in the knowledge production function and these measures cannot capture the extent of TEs made by developing countries.[3] Thus, this dissertation constructs an index of TEs

[3] Different studies irrespective of if those are based in the developed or developing countries context, use different measures to operationalize innovation. In the knowledge production function, the investment into R&D strengthens the stock of knowledge in a country that leads to innovation, and further raises their output (Griliches, 1979). The motivation is to patent, the principal innovation output of the R&D investment – in such cases higher investment in innovation input would encourage inventions, innovations and patents (Griliches, 1990). A nation's innovation capabilities, technology growth, and knowledge capital, would improve through effective R&D activities.

using both input and output indicators of innovation to analyse the TEs made by developing countries – efforts that contribute towards its exports.

### 1.3 TEs and Exports

From Solow growth models to endogenous growth models, technology is at the heart of the economic development process. Furthermore, lessons from trade liberalization show that export orientation rather than infant industry protection should be the strategy for economic development. Developing economies motivated to become internationally competitive make extensive technological efforts to raise their export performance. In the context of developing countries, studies find a mixed evidence on the relationship between innovation and export performances (Dasgupta and Siddharthan, 1985; Willmore, 1992; Guan and Ma, 2003; Bhat and Narayan, 2009; Molina-domene and Pietrobelli, 2012).

In the empirical literature on the relationship between innovation and exports separately for developed and developing countries, we find that the impact of innovation on export performances is not clear, particularly for developing countries. The empirical studies in this area are yet to reach a strong consensus on such a relationship. Thus, it is pertinent to study from the perspective of developing countries the gain through the improvement in TEs and concomitantly in exports.

Extant literature highlights that innovation varies with industries and distinguishes industries into high, medium and low technology industries depending upon the R&D expenditure and patent intensity. The export intensity and performance of firms from different industries is therefore expected to vary. Montobbio and Rampa (2005) argue that the relationship between technological activities and export performances are different in low-tech, medium-tech and high-tech exports, as these are dissimilar in terms of learning potential, growth opportunities, scope of upgrading and spillover to the rest of the economy. Studies show that the share of high technology product in the exported countries increases tremendously after the introduction of the product patent, influencing its export performance and the global competitiveness (Chen and Puttitanun, 2005; Ivus, 2010). The growth of high-tech exports is because of the technology spurts or international production sharing (Mani, 2000; Srholec, 2007). Mani (2000) finds that majority of developing countries' high-tech exports are due to multinational enterprises with very little local R&D. Srholec (2007) suggests that international fragmentation of production plays an important role for the significant performances of developing countries' in high-tech exports. Based on this discussion, this dissertation utilises high technology as a measure of exports. Table 1.1 provides the data of high-technology exports as a percentage of total manufacturing exports. Interestingly, for the high-income countries, the high-technology exports as percentage of manufacturing exports are stagnant, however, for middle-income countries, there is a rising trend.

**Table 1.1: High-technology exports as % of manufacturing exports across select countries**

| Country / Year | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|
| **Middle Income** | 20.12 | 21.07 | 21.03 | 21.53 | 22.26 |
| Brazil | 12.05 | 13.14 | 14.34 | 13.31 | 12.95 |
| China | 32.15 | 30.43 | 30.25 | 30.89 | 31.44 |
| India | 7.67 | 7.99 | 7.65 | 7.35 | 9.01 |
| South Africa | 5.97 | 6.97 | 6.24 | 5.22 | 5.32 |
| Zambia | 1.09 | 7.66 | 31.06 | 4.49 | 2.00 |
| **High income** | 20.74 | 19.63 | 20.49 | 20.41 | 20.22 |
| Germany | 17.01 | 17.89 | 18.22 | 15.86 | 15.78 |
| France | 26.59 | 28.36 | 28.08 | 26.09 | 25.92 |
| Japan | 19.16 | 18.07 | 17.34 | 17.56 | 17.27 |
| United Kingdom | 23.55 | 22.67 | 23.98 | 23.14 | 22.64 |
| United States | 23.12 | 21.95 | 23.01 | 19.69 | 18.90 |

Note: We follow World Bank (2016) classification for high- and middle-income countries.
Source: World Development Indicators, World Bank

## 1.4 PRs, TEs, and Exports

Proponents of patent policy reforms argue that PRs affect innovation and stimulate economic growth. Earlier studies, however, seem to show that the impact of strong PRs on innovation and the economic growth of developing countries is predominantly negative (Nogues, 1993; Watal, 2000; Kumar, 2003). At present, though, the innovativeness of developing countries may have reached a stage where it can be positively affected by strong PRs. The narratives of innovation and exports, in empirical studies, are important for national competitiveness at the country (macro) and firm (micro) levels. At the country level, innovation stimulates industrial productivity and exports growth, and innovation measures firms' competitiveness at the micro-level. According to the international trade models, developed by Vernon (1966), Krugman (1979), among others, innovation activities play a significant role for success in the international markets, and these models argue that there is a positive linkage between innovation and exports. Trade and growth models envisage the relationship between innovation and exports. Usually, it is argued that countries' export promotion strategy plays a significant role in economic prospects. Innovation plays a major role in determining exports, and hence, economic growth of a country by strengthening domestic industries. The contribution of exports to economic growth has been empirically documented in various studies (Srholec, 2007; Falk, 2009). An increase in the competition of exports markets may lead to a boost in economic efficiency, and that further contributes to productivity by technology diffusion and learning by doing.

The role of PRs protection in TEs and exports performances is an important factor in the economic growth of a country. However, enormous theoretical and empirical literature predominantly study the impact of PRs protection on countries' economic growth including different channel of growth, namely to stimulate R&D, productivity growth and technology transfer (Gould and Gruben, 1996; Park and Ginarte, 1997; Thompson and Rushing

1999; Yang and Maskus, 2001; Kanwar and Evenson, 2003; Schneider, 2005; Chen and Puttitanun, 2005; Falvey et al., 2006; Allred and Park, 2007; Kim et al., 2012; Sweet and Maggio, 2015). As suggested in the promotional channel of gains from PRs, strong protection is expected to stimulate domestic innovation, whereby a firm may invest more in R&D in the expectation that it will profit from the newly developed product or process.

Ongoing studies explore the impact of PRs either on economic growth or on innovativeness through R&D expenditure and patenting.[4] It is not evident in these studies how the changes in innovativeness translate into economic growth. In this dissertation, we study the impact of PRs on the TEs of a country and their contribution to high-technology exports. We combine the TEs made by countries and their contribution to high-technology exports in order to explain a mechanism through which strong PRs contribute to economic growth, as such a channel remains unexplored in the current literature.

Furthermore, this doctoral work is based on high-technology exports data where extant literature has established the industry specificity of the patent-rights influence on innovation. Recent studies in international trade explore the extensive and intensive margins of trade. The extensive margin is defined as a change in the number of trading partners or number of products traded. It captures the increase in variety of exports and shows the changes in tastes of the importer, as consumers abroad seek to try new goods. The intensive margin is defined as the change in volume of trade among two countries. It captures how exports are spread across varieties. As we discussed earlier, there are variations among the developing countries in terms of technology efforts and its influence on export growth. Hence, we

[4] See for instance, Gould and Gruben, 1996; Park and Ginarte, 1997; Chen and Iyigun, 2011.

are interested to understand the patterns of bilateral trade and the product dimension cross countries at disaggregated level.

Studies examine the impact of several trade policies on the margins of trade, namely, trade liberalisation, membership in multilateral organisation, hosting mega-events (namely, the Olympics and the World Cup), and PRs on bilateral trade flows (Rose and Spiegel, 2011; Dutt et al., 2013; Ndubuisi and Foster, 2018). However, these studies do not take into consideration the TEs of the country. Also, such channels remain unexplored in the current literature. Therefore, we explore the impact of TEs on bilateral exports by decomposing total exports into two margins of trade, utilising disaggregated products level export data.

## 1.5 Motivation and Research Gap for the Dissertation

The changes of PRs since the last twenty-five years in many developing countries following the requirement to comply with the TRIPs agreement provide an interesting research context to undertake the study. These changes are likely to influence the level and growth of innovation activity, particularly for developing countries. The extant literature exploring the promotion channel connecting PRs and innovation finds mixed results.

Lall (2003) has argued that developing countries' innovation activity is a process of learning to use imported technologies efficiently rather than to innovate on the technological frontier and its exporters face many problems in order to enter into the global market and access information, due to higher production cost. Hence, these countries are not directly involved in innovating and pushing the frontiers of knowledge. Instead, such economies acquire, adapt, and improve the existing technologies from the international technology market. Accordingly, the existing evidence on the role of innovation in developing countries' exports is mixed. Shin et al. (2016) argue that within the developing countries, the technology levels vary leading to a complex picture. For example, developing countries' innovation is based on adaptive R&D for high-technology products. Evidently, countries export such products if these are not protected in the international markets.[5] Moreover, for some developing countries innovation levels have evolved up the technology ladder in a few sectors to produce and export patented product that may be in the first stage of product cycle development.[6]

Most of the studies highlight the developed countries' perspective, with developing countries as a net consumer of new products. The impact of a source country's PRs on its export through the stimulation of TEs remains unexplored in the literature. The impact of stronger PRs protection varies across countries, depending on existing technological efforts and the ability to innovate. Studies do not examine the influence of the source countries' PRs protection on their TEs. From the promotional channel of gains from PRs, as discussed earlier, strong protection is expected to stimulate domestic innovation. Therefore, in this dissertation, we are interested to study the relationship between PRs and exports conditioned by TEs of the source country at both aggregated and disaggregated level.

### 1.6 Objectives of the Dissertation

According to Article 7 of TRIPs agreement, "The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations".

Based on the above discussions, the dissertation outfits as its central hypothesis that the source countries' PRs protection supports countries'

[5] India's generic drugs provide an example of such products.
[6] Patenting and exports of solar panel is a case of China.

technological efforts and further, its contribution to countries' exports along with trade margins—extensive and intensive margin of trade.

The principal research questions are:

4. Do countries' patent rights support technological efforts?
5. Do technological efforts contribute to exports?
6. Do countries' technological efforts influence export margins—extensive and intensive margins of exports?

The objectives of the dissertation are:

1. To examine the impact of source countries' patent rights protection on technological efforts.
2. To investigate the impact of source countries' technological efforts on exports.
3. To study the impact of source countries' technological efforts on bilateral exports along with export margins—extensive and intensive export margins.

## 1.7 Database and Methods

### 1.7.1 Data

We undertake three studies to address the above-mentioned objectives. As the main objective is to focus on the PRs on innovation and then exports, the first essay undertakes an extensive review of the literature. Furthermore, we strengthened the review by meta-regression analysis. To investigate the relationship between PRs and innovation, we went through 14 empirical studies containing 145 estimates undertaken during 1995-2019. The second part of the study focuses on the impact of innovation on exports based on 27 empirical studies containing 249 estimates during 1996-2019.

For the second essay, this dissertation utilises panel data for 67 countries during 1996-2014. We estimate the relationship between PRs, TEs and exports by subgroups of high-income and middle-income countries based on the World Bank (2016) classification of economies. To conduct an empirical investigation, important sources of data are World Development Indicators (WDI), Park (2008), UN Comtrade, World Integrated Trade Solution (WITS), World Intellectual Property Organization (WIPO).

For the third essay of the dissertation, we utilise product-level exports data to analyse the relationship between technological efforts and export margins— extensive and intensive margins for 56 countries during 1996-2014. Export data are extracted at the Harmonised System (HS) 6-digit level of disaggregation from UN COMTRADE. Following Delgado et al. (2013) classification, we take high PRs sensitive products that are classified in the Standard International Trade Classification (SITC), then we made concordance between SITC and HS.

### 1.7.2 Methodology

In the first essay, we focus on the literature survey and utilise meta-regression analysis (MRA) to tests whether the empirical findings are sensitive to various measures employed, and hence, identifying possible policy implications across countries. MRA harmonizes empirical survey results, combining the findings of various studies that use different data and methodologies, and presents a clear and descriptive result.

In the second essay, we use panel data analysis to quantify the effect of PRs protection on technology effort and in turn its influence on high-technology exports. To measure countries technological efforts, we construct a technology efforts (TEs) index by utilising principal component analysis (PCA), including both input and output indicators of innovation. In the estimations, both fixed effect (FE) and random effect (RE) regression techniques are applied to estimate the coefficients. Finally, the choice between FE and RE technique is based on the Hausman specification test.

In a gravity model (GM) setting, we examine the impact of technological efforts on exports along with margins of trade, to understand the bilateral export flows across countries. We develop the model with the key variables, namely, exporter TEs, importers PRs, and their interactions. We address major challenges and solution, namely, multilateral resistances (MRs) term, zero trade flows, heteroskedasticity of exports data, endogeneity issues and bilateral trade costs, in order to obtain consistent estimates. To build the margins of exports, we apply the count method to construct the export margins. We implement the Poisson Pseudo-Maximum Likelihood (PPML) estimation technique as an appropriate methodology to estimate the impact of technological efforts on bilateral exports along with the extensive and intensive margin of trade.

### 1.8 Significance and Scope of the Dissertation

This dissertation is a collection of three essays, each representing an individual paper. The first essay of this dissertation undertakes an extensive review of literature on the impact PRs on innovation and then exports. The review is further strengthened by meta-regression analysis to understand the sensitivity of results of empirical studies to data, the period of study and most importantly to the level of economic development of sample countries. The second essay of this dissertation study how patent rights protection augments countries technological efforts that further contributes to countries' high-technology exports. We provide an incremental perspective on an existing channel through which countries gain from PRs. This study constructs a technology efforts (TEs) index using principal component analysis (PCA) using both input and output indicators of innovation to analyse the technology efforts made by a country that contributes toward its export capacity across countries. As explained, there are variations in the technology efforts of middle-income countries that are captured through the index. We approach the problem from the source country perspective to introduce the variation in terms of host country factors. Further, as these economies have implemented patent policy changes to comply with TRIPs, such a study will provide an empirical evidence about the impact of the agreement. In a gravity model setting, we study the impact of technological efforts on bilateral high-technology exports along with margins of trade—extensive and intensive margin of exports. Using 6-digit product-level export data, we have observed a sharp increase in exports along with extensive and intensive margins through countries' technological efforts. Based on the economic development, we find that countries' technological capacity augments more varieties of products by implementing the Poisson Pseudo-Maximum Likelihood (PPML) estimation technique.

### 1.9 Organisation of the Dissertation

The present thesis is organised as follows: Chapter 2 provides first essay of the dissertation, namely, patent rights protection, innovation, and exports: a meta-regression analysis. We undertake an extensive review of literature on PRs on innovation and then exports. To understand the sensitivity of results of empirical studies to data, the period of study and most importantly to the level of economic development of sample countries, we present meta-regression analysis and major findings.

Chapter 3 presents the second essay of the dissertation, namely, patent protection, technological efforts, and exports: an empirical investigation. We provide clear motivation on the impact of source countries' PRs protections on technological efforts, and its contributions to exports. Next subsection of this chapter discusses the specific state of art, the research gaps and provide clear hypothesis on such relationships. Next, we present data, methods and variable constructions. In this chapter, we present the construction of technology efforts index for this dissertation. We split data into different income groups and this helps us measure the varying effects of technological efforts, exports, and PRs by income group. Next, we provide empirical results, discussion and sensitivity analysis. Finally, we discuss summary and conclusion of this chapter and provide specific policy implication and limitation of this essay.

Chapter 4 presents the third essay of this dissertation, namely, the impact of technological efforts on the extensive and the intensive margins of trade. We introduce the context and clear motivation for this essay. Next sub-section of this chapter sets the background by reviewing the existing evidence on TEs, PRs, exports, and trade margins by describing their inter-relationship and provides the hypothesis. Next, we present methodology, estimation challenges, details on the variables and data. In next sub-section, we discuss the results of the empirical exercise undertaken to investigate gains from exports classification at disaggregated level through established channels of technological efforts. Following section provides robustness checks of the results. The last sub-section summarises and concludes the chapter.

Chapter 5 presents a summary of the three essays. Next, there is a synthesis of the findings to draw policy implications. The last subsection of this chapter notes certain limitations of the dissertation and accordingly outlines directions for future research.

# Chapter 2

# Patent Rights Protection, Innovation, and Exports: A Meta Regression Analysis

## 2.1 Introduction

Developing countries have changed their intellectual property rights (IPRs) regime to comply with the Trade-related Aspects of Intellectual Property Rights (TRIPs) agreement under the World Trade Organization (WTO). This agreement influenced the domestic patent rights (PRs)-related legislature of the member states within a timeframe set by the agreement. Following these changes, most of the developing countries now comply with TRIPs. Article 65 of the TRIPs agreement provides a specific timeframe to developing countries, least developing countries (LDCs), and transition economies for applying its provisions.[7] There are extensive studies on PRs and innovation that originated during and after TRIPs negotiations.

Patent rights (PRs) play a significant role in countries' innovation and technological development. Considering the potential impact of PRs on innovation in advanced countries, many studies argue that the returns to innovation are increased by strong PRs protection (Landes and Posner, 2003; Scotchmer, 2004; Allred and Park, 2007a). Empirical studies in the area have yet to reach a robust consensus about the relationship between PRs' protection and innovation (Ginarte and Park, 1997; Chen and Puttitanun, 2005; Allred and Park, 2007). Therefore, we are interested in examining the impact of patent right protections on innovation across

[7]All developing, and transition economies have been granted a period for four years that is up to 1 January 2000 for making legislative changes. Special transition rules apply in situation where developing countries do not provide product patent protection in a given area of technology. In this case, transition period was increased by 10 years up to 1 January 2005.

countries by conducting a meta-analysis. Many studies suggest that the impact of countries' PRs on innovation depends upon countries' technological activities (Ginarte and Park, 1997; Schneider, 2005).

Endogenous growth theory postulates that technology adaptation, innovation, and imitation are the key factors for the technological progress of a country (Romer, 1990). Such progress contributes to the economic growth of an economy by determining its international competitiveness. Vernon (1966) stresses the importance of technology factor in international competition based on country-specific advantage, and such competitive advantages resulted in innovating new products and processes. Studies consider innovation as an exogenous variable and envisage that innovation affects the export performance of a country (Posner, 1961; Vernon, 1966; Krugman, 1979).

Innovation plays a major role in determining exports and hence economic growth of a country by strengthening domestic industries. The existing evidence on the role of innovation in developing countries exports is mixed (Dasgupta and Siddharthan, 1985; Willmore, 1992; Chadha, 2009; Shin et al., 2016). Empirical studies in this area are yet to reach a consensus about the relationship between innovation and exports. Therefore, this doctoral work examines the impact of innovation on exports, utilizing a meta-regression analysis (MRA).

This chapter is organised as follows: Section 2.2 presents the review of the literature; in the subsection, we review the literature on the relationship between patent rights and innovation, and the relationship between innovation and exports. Section 2.3 presents the MRA database and methodology. Section 2.4 summarises the meta-regression results. Section 2.5 concludes the chapter.

## 2.2 Literature Review

### 2.2.1 Patent Rights (PRs) and Innovation

According to the prospect theory, strong PRs provide innovators with incentives to commercialize and organise the market better for follow-on innovation (Kitch, 1977). However, with these positive influences, innovation may be negatively influenced by strong PRs owing to problems encountered in obtaining permission to use patented technologies for technological exchange; consequently, increasing transaction costs for technologies (like biotechnology) that develop cumulatively (Williams, 2013). The condition is that "the transaction costs may particularly harm research and innovation when patentees hold rights to research tools, or where innovation is a cumulative and sequential process" (Allred and Park, 2007, pp. 881).

Enormous theoretical and empirical literature predominantly study the impact of PRs protection on countries' innovation and economic growth including different channels, namely to stimulate R&D, productivity growth and technology transfer (Gould and Gruben, 1996; Park and Ginarte, 1997; Thompson and Rushing 1999; Yang and Maskus, 2001; Kanwar and Evenson, 2003; Schneider, 2005; Chen and Puttitanun, 2005; Falvey et al., 2006; Allred and Park, 2007; Kim et al., 2012; Sweet and Maggio, 2015). Gould and Gruben (1996) suggest that PRs' protection is a significant determinant of economic growth. Park and Ginarte (1997) provide differential effects of the PRs on economic growth. They find strong PRs influence the R&D activities of the developed countries and not of the developing economies. Thompson and Rushing (1999) also empirically evaluate the influence of PRs on economic growth. They find a significant positive relationship between PRs and economic growth in developed countries. Kanwar and Evenson (2003) show stronger PRs protection can help spur innovation and technological progress, which in turn, should impact growth positively. Moreover, Falvey et al. (2006) find the effect of

PRs on growth for low-and high-income countries is positive and statistically significant, but not for middle-income countries.

Arrow (1962) suggests that PRs play a major role in R&D activities. Griliches (1990) analyses the relevance of the patent data vis-à-vis R&D expenditure in capturing innovation activity and establishes R&D as an input in the knowledge production function that leads to an output in the form of patent. This study uses both the measures (namely, R&D expenditure and patenting) by the industry to capture the innovation activity in the Indian manufacturing sector. In this context, Kanwar and Evenson (2003) have examined the relationship between innovation and PRs' protection and found that the index of PRs had a significant positive effect on R&D investment. Ginarte and Park (1997) find that strong PRs influence R&D activities of developed countries, but not in developing ones. Schneider (2005) finds that stronger patent rights have a positive effect on innovation in developed countries, while Chen and Puttitanun (2005) confirm the existing U-shape relationship between innovation and PRs protection of a developing country. Interestingly, Allred and Park (2007) examine the effects of PRs on different aspects of innovation activities, namely, R&D and patenting. They find that the impact of PRs on innovative activity is very complex, and subsequently, it depends on the initial level of PRs' strength and differs by countries' level of economic development. By and large, for developing countries, the impact of PRs on innovation is negative, that is, for domestic patenting. For developed countries, there is a positive effect of PRs on R&D and domestic patenting, negative for foreign patenting, after it reaches the threshold level of PRs protection. Sakakibara and Branstetter (1999) study the scope of PRs for creating an innovative environment based on evidence from Japan's 1988 patent law reforms and found that patent reform had not created any change in R&D spending and productive innovation. Woo et al. (2015) analyse the effects of PRs on industry commercialisation, sequential innovation, and industry-specific innovation. The results show that PRs indirectly influence R&D in the discrete industry (chemical) and have a statistically insignificant effect on complex industries (electronic and machinery). This study mainly argues that innovation does not occur in weak PRs protection countries, such as developing countries.

Studies explore the impact of PRs either on economic growth or on innovativeness through R&D expenditure and patenting. Proponents of patent reform argue that PRs affect innovation and stimulate economic growth. Earlier studies, however, seem to show that the impact of strong PRs on innovation and the economic growth of developing countries is predominantly negative (Nogues, 1993; Watal, 2000; Kumar, 2003). At present, though, the innovativeness of developing countries may have reached a stage where it can be positively affected by strong PRs. The existing narrative review finds that the impact of PRs on innovation is not clear across developing countries.

### 2.2.2 Innovation and Exports

The conventional trade theory (neoclassical international trade model) postulates that the difference in factor endowment measures country's export and establishes the comparative advantage of countries. It assumes that technology has no role to play as it is freely available to all and hence fails to provide due attention to the effect of technology on international trade. Later developments in the trade theory, recognises technology as an important determinant of international competitiveness and exports (Posner, 1961; Vernon, 1966; Krugman 1979). Vernon (1966) stresses the importance of technology factor in international competition based on country-specific advantage, and such competitive advantages result in innovating new products and processes. Krugman (1979) suggests that technological diffusion is an important element of international trade, primarily, North (developed countries) innovates that gets diffused to the South (developing countries), and it is shaping the trade. In the South, the diffusion of technological innovation occurs through a certain level of imitative, adaptive and absorptive capability.

We review the empirical literature by examining the relationship between innovation and exports separately for developed and developing countries, highlighting the conditional factors like firms' size and ownership, types of innovation, industry specificity, domestic conditions and different measures used by studies to operationalise innovation (R&D, patent and technological capability).

Soete (1987) studies Organization for Economic Co-operation and Development (OECD) countries' 40 industries and suggests that patents play a significant role in a country's export performance. Van Hulst et al. (1991) find that there is a positive association between the pattern of export specialisation and the technology specialisation in the case of Germany, the Netherlands and Sweden. Caldera (2010) investigates the relationship between innovation and export behaviour of Spanish firms and finds a positive effect of firm innovation on export performance. Ganotakis and Love (2011) study the relationship between R&D, product innovation, and exporting for a sample of new technology-based UK firms. By using a recursive system of the R&D-innovation-exporting relationship, this study finds innovators are certainly expected to export, however, there is no evidence about the positive impact of innovation on successive export intensity.

In the context of developing countries, studies find a mixed evidence on the relationship between innovation and export performances. Dasgupta and Siddharthan (1985) suggest that largely goods of Indian exports consist of low technology. In the case of Brazil, Willmore (1992) finds that R&D expenditure has no significant effect on its exports. Zhao and Li (1997) study the relationship between R&D and export propensity of China's manufacturing firms. The study finds a positive influence of R&D on export propensity and export growth. Guan and Ma (2003) find that innovation capability dimensions are important in determining Chinese firms' export performances. Moreover, Bhat and Narayan (2009) argue that achievement of technological capabilities (in-house R&D) is a significant in determining export performances of the Indian chemical industry. Further, Molina-domene and Pietrobelli (2012) find that technological capabilities positively influence export performance in Latin American countries. Chadha (2009) finds that foreign patent rights (technology proxy) have a positive impact on Indian generic pharmaceuticals exports, by considering the later stage of product cycle development. She also suggests that developing countries have the potential to establish in the international market through innovation skills (by using patents). Interestingly, Veeramani et al. (2018) find that the export growth of India is inclined in favour of technology-intensive- and human capital products as compared to unskilled labour-intensive products.

By examining the impact of innovation on exports of Vietnam small and medium-sized enterprises (SMEs), Nguyen et al. (2008) suggest that innovation determines Vietnamese SMEs exports. Añón Higón and Driffield (2011) examine the relationship between innovation activities and export performance of UK SMEs. Interestingly, they find that the role of size is relevant irrespective of the level of development of countries from which the firm is originating.

Studies argue that there are different type of innovation, namely, product and process innovation, with differential impact on firm performance (Nassimbeni, 2001; Basile, 2001; Roper and Love, 2002; Añón Higón and Driffield, 2011). Nassimbeni (2001) find that there is no relationship between process innovation and export probability. However, by increasing competitiveness and opening new markets, Basile (2001) and Roper and Love (2002) suggest that product innovation positively affects export intensity. Añón Higón and Driffield (2011) examine the relationship between innovation activities (distinguishing product from process innovation) and export performance of UK SMEs. They consider product and process innovation independently and find that innovation activities stimulate exports. They don't find strong evidence that process innovation increases the probability to export beyond product innovation when they consider interdependence between both innovation activities. Mitra and Jha (2015) suggest that Indian firms' R&D expenditure not necessarily mean actual technological innovation. Even though such R&D expenditure bring in an improvement in product quality and efficiency by processing of by-products and efforts, all of which may result in employment gains.

Studies use different measures to operationalize innovation, irrespective of the developed or developing countries context. In the knowledge production function, the investment into R&D strengthens the stock of knowledge in a country that leads to innovation, and further raises their output (Griliches, 1979). The motivation is to patent, the principal innovation output of the R&D investment–in such cases, higher investment in innovation input would encourage inventions, innovations and patents (Griliches 1990). A nation's innovation capabilities, technology growth, and knowledge capital would improve through effective R&D activities. Many empirical studies underscore the relationship between innovation (different measures to operationalize innovation) and exports, namely, Zhao and Li (1997), Montobbio and Rampa (2005), Chadha (2009), Bhat and Narayan (2009), Goldar (2013), Sandu and Ciocanel (2014).

Guan and Ma (2003) find that innovation capability dimensions are important in determining Chinese firms' export performances. The innovation capability dimensions (namely, learning, R&D, manufacturing, marketing, organizational, resource allocating, and strategy planning) is a special asset of a firm, and are tacit and non-modifiable. They argue that such innovation capability is an important aspect of competition as the ability to promptly introduce new products and to adopt new processes. They suggest that such capability is the crucial factors in the improvement of export performance and international competitiveness of Chinese firms.

Further, in the doctrine of the evolutionary theory of technical change, Molina-domene and Pietrobelli (2012) focus on the technological capabilities approach at the firm level. They have criticized the measurement of capability approach, which is based on either input indicator (R&D) or output indicator (patent). Hence, to measure technological capabilities, this study constructs a technology index, considering the firm's technical functions such as investment, production and linkage activities. They find that technological capabilities positively influence export performance in Latin American countries. Recently, Nemlioglu and Mallick (2020) investigate the impact of innovation on firms' valuation and its uncertainty, considering the innovation intensity and leverage in pre- and post- 2008 financial crisis periods for the UK. They find that R&D, patent, and advertising intensity enhance market valuation for large firms in the post-crisis period in contrast with the pre-crisis period. They also study the impact of sectoral heterogeneity on valuation. They suggest that the high-tech manufacturing firms benefit from patenting and R&D and the low-tech firms benefit from trademark and advertising in the post-crisis period.

Extant literature highlights that innovation varies with industries and distinguishes industries into high, medium and low technology industries depending upon the R&D expenditure and patent intensity. The export intensity and performance of firms from different industries are therefore expected to vary. Montobbio and Rampa (2005) find the relationship between technological activities and export performances are different in low-tech, medium-tech and high-tech exports, as these are dissimilar in terms of learning potential, growth opportunities, scope of upgrading and spillover to the rest of the economy. If a country expands its innovative activities in industries with increasing levels of technological opportunities in high technology sectors, then technological activity enhance countries' export performance. In terms of factors affecting market share dynamics, medium- and low-tech sectors are more homogeneous in nature. When targeted toward industries growing above average worldwide, in developing countries, the low levels of competitiveness can be overcome. Studies show that the share of high-technology product in the exported countries increases tremendously after the introduction of the product patent, influencing its export performance and the global competitiveness (Chen and Puttitanun, 2005; Ivus, 2010).

A study by Lall (2000), through an analysis of the relationship between technological structure and manufactured exports performance, finds that developing countries are exporters of high-tech products. This study concludes that there is a significant performance of high-tech exports, which may be 'something statistical illusion' following from the specialization in the labor-intensive processes within high-tech-intensive industries. Interestingly, the growth of high-tech exports is because of the technology spurts or international production sharing (Mani, 2000; Srholec, 2007). Mani (2000) finds that majority of developing countries' high-tech exports are due to multinational enterprises with very little local R&D. Srholec (2007) suggests that international fragmentation of production plays an important role in the significant performances of developing countries' in high-tech exports.

Linder (1961) postulates that new products fit the demand condition in countries' home market than in the foreign market. In determining the rate and direction of technical change, Dosi (1988) argues that industries demand play an important role. Moreover, in the home market, technological capacity and characteristics of demand construct firms' innovation in response to the local innovation opportunity. Innovation has been polished in a local feedback process among users and manufactures in the local market, and there is an argument that such innovation is successful in the international market. There is also a suggestion that in domestic/local market innovation opportunity is efficient. Beise-Zee and Rammer (2006) investigate the impact of local adaptation of innovation on exports and test whether certain local market's characteristics influence exportability of innovation by using survey data from the German innovation survey of 4,786 firms in the manufacturing and service industries. They find that domestic demand structure and export orientation encourage exports success.

#### 2.2.3 Research Gap

Existing narrative reviews offer the following: The impact of PRs on innovation is not clear across countries. There are not enough studies which find the significant effect of PRs on innovations in developing countries. In the empirical literature on the relationship between innovation and exports separately for developed and developing countries, we find that impact of innovation (including R&D, patent, product innovation, process innovation, innovation capability and technological capability) on export performances is not clear, particularly for developing countries. The empirical studies in this area are yet to reach a strong consensus on such relationship. There is also a lack of robust consensus on the impact of innovation on exports conditioned on the type of innovations, industry specifications, firms' specifications, and domestic conditions. Thus, it is pertinent to study from the perspective of developing countries the gain through the improvement in innovation and concomitantly in exports by utilizing meta-regression analysis.

### 2.3 Meta-Regression Analysis (MRA): Data and Methods

#### 2.3.1 Meta Regression Analysis (MRA)

The purpose of meta-regression analysis (MRA) is to harmonize empirical survey results, combining the findings of various studies that use different data and methodologies, and present a clear and consensual descriptive result to provide insights by challenging estimations with actual research. Glass (1976) denotes MRA as the regression analysis of regression analyses. According to Glass (1976), "meta-analysis refers to the statistical analysis of a large collection of results from individual studies for the purpose of integrating the findings. It connotes a rigorous alternative to the causal, narrative discussions of research studies which typify our attempts to make sense of the rapidly expanding research literature" (p.3).

MRA is a specific method that explains the heterogeneity in the effect sizes reported by primary studies. Following Stanley and Jarrell (2005), MRA comprises the estimation of a standard regression model as follow:

$$b_j = \beta + \sum_{k=1}^{k} \alpha_k Z_{kj} + e_j \qquad (j = 1, 2, \ldots\ldots L) \qquad (1)$$

Where, $b_j$ is the reported estimates of $\beta$ of the *j*th study in the literature included of L studies; $Z_{kj}$ corresponds to the K meta-independent variables, which measures relevant characteristics of the empirical studies, and it shows the systematic difference from other studies' results. $\alpha_k$ is MRA coefficient that represents the bias effect of particular study's characteristics, and $e_j$ is the meta-regression disturbance term. MRA synthesizes the empirical studies by identifying relevant characteristics of the empirical studies and showing those changes in $Z_{kj}$. For the empirical economic investigations, reference of data determines the final specification of the model. In this study, we estimate the MRA to find the difference in studies' characteristics and explain the effect size heterogeneity. We capture these differences by including dummy variables of primary studies in Tables 2.1 and 2.2, respectively.

**Table 2.1: Moderating variables (PRs and innovation)**

| Variables | Type | Measures |
|---|---|---|
| Journal | Dummy | 1 if study published as journal article; 0 if otherwise |
| Data Type | Dummy | 1 if panel data is used; 0 if otherwise |
| Developed country | Dummy | 1 if sample from developed countries; 0 if otherwise |
| Developing country | Dummy | 1 if sample from developing countries; 0 if otherwise |

| | | |
|---|---|---|
| GDP | Dummy | 1 if study include GDP as a control variable; 0 if otherwise |
| Openness | Dummy | 1 if study include openness as a control variable; 0 if otherwise |
| Education | Dummy | 1 if study include education as a control variable; 0 if otherwise |

**Table 2.2. Moderating variables (innovation and exports)**

| Variables | Type | Measures |
|---|---|---|
| Journal | Dummy | 1 if study is published as journal article; 0 if otherwise |
| Country level | Dummy | 1 if country level data is used; 0 if otherwise |
| GDP | Dummy | 1 if study include GDP as a control variable; 0 if otherwise |
| Distance | Dummy | 1 if study include distance as a control variable; 0 if otherwise |
| Profitability | Dummy | 1 if study include Profitability as a control variable; 0 if otherwise |
| Size | Dummy | 1 if study include size as a control variable; 0 if otherwise |

### 2.3.2 Data

After framing the research question, we undertake a comprehensive search of literature available on Google Scholar, JSTOR and other sources, and build our sample from the English language sample. We searched in the title, abstract of published works, working papers and conference papers for any reference to “intellectual property right” and “innovation”; “PRs and innovation” since 1996 and we have obtained nearly 100 studies. However, keeping in mind the objectives of our study, we find that only 14 empirical studies satisfy our purpose. Potential relevant publications have been identified and screened. Studies have excluded on the basis of the titled and abstract of the papers. Particular condition is considered for inclusion of the studies for meta-regression analysis, such as exposer of interest.

Out of the 14 papers, one is conference paper. Most papers are cross-country studies; three studies are about the developed world, two country specific studies and only one study is based on developing countries. Many studies use patent and R&D data as the measure of innovation. However, two studies use different indicators to measure innovation, i.e. economic complexity index and technology efforts index. Interestingly, all studies employ panel data analysis. Most studies use Ginarte and Park (1997), and Park (2008) PRs index as a measure of patent rights strength.[8] Two studies use Park (2008) PRs index (while including other index) and only one study uses property right alliance (2016) PRs index to measure the strength of PRs. Table 2.3 presents the list of papers included in the meta-regression database, the number of estimates, and the average effect size of the studies. The estimates of PRs on innovation vary between -4.389 (Allred and Park, 2007) and 11.2 (Cho et al., 2015), with 37 negative values and 108 positive values.

**Table 2.3: List of papers included in the meta-regression database: PRs and innovation**

| Study | No. of countries | Time-period | Measurement of Innovation | No. of Estimates | Ave. Effect Size |
|---|---|---|---|---|---|
| Allred and Park (2007) | 100 | 1965-2000 | R&D Patent | 13 | -0.49 |
| Allred and Park (2007a) | 121 | 1960-2000 | R&D | 2 | 2.3 |
| Chen and Puttitanun (2005) | 64 | 1975-2000 | Patent | 4 | 5.05 |
| Cho et al. (2015) | Korea | 1995-2009 | R&D Patent | 12 | 2.12 |
| Cho and Kim (2017) | USA | 2007-2010 | Patent | 5 | -0.39 |
| Hudson and Minea (2013) | 62 | 1980-2009 | Patent | 9 | -0.023 |
| Kanwar & Evenson (2003) | 32 | 1981-1990 | R&D | 17 | 0.81 |
| Kanwar (2007) | 44 | 1981-2000 | R&D | 1 | 1.14 |
| Kim et al. (2012) | 70 | 1975-2003 | Patent | 9 | -0.01 |

[8] Park and Ginarte (1997) develop the PRs index that indicates the strength of IPR protection in each country. The index ranges in value from 0 to 5, higher values of the index reflecting stronger levels of protection. Further, Park (2008) extends the index to more countries and longer time.

| | | | | | |
|---|---|---|---|---|---|
| Papageorgiadis and Sharma (2016) | 48 | 1998-2011 | Patent | 3 | 1.98 |
| Panda et al. (2020) | 67 | 1996-2014 | Technology Effort Index | 6 | 0.12 |
| Sweet and Maggio (2015) | 94 | 1965-2000 | Economic Complexity Index | 43 | 0.09 |
| Leger (2006) | 68 | 1970-1995 | R&D | 15 | 0.57 |
| Woo et al. (2015) | 12 | 1995-2005 | R&D | 6 | 0.14 |
| **ALL** | | | | **145** | |

For account relationship between innovation and exports, we also searched in the title, abstract of the published works, working papers and conference papers for any reference to "innovation" and "exports"; "innovation and exports" since 1996[9] and we have obtained nearly 250 studies. However, keeping in mind the objectives of our study, we find that only 27 empirical studies that contain 249 estimates fulfil the criteria for our MRA. Out of the 27 papers, two are conference papers. Interestingly, maximum studies employ panel data analysis. Most papers are country-level studies and firm-specific studies, and they use survey data as well. 15 studies are on the developed world, 8 studies are on developing countries, and only 4 studies are on mixed data (including both developing and developed countries). Table 2.4 presents the list of papers included in the meta-regression database, the number of estimates, and the average effect size of the studies. The estimates of innovation on exports vary between -11.01 and 36.22, with 231 positive value and only 18 negative values.

[9] The choice of the survey of literature is based on the introduction of TRIPs in 1995. Studies suggest that changes in patent rights (PRs) have been introduced to incentivize innovation in developing countries after the passage of the agreement on TRIPs under WTO.

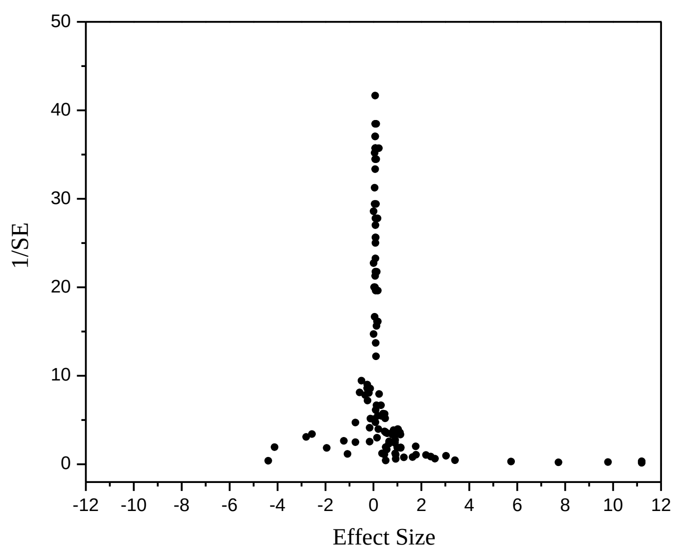
**Table 2.4. List of papers included in the meta-analysis database: innovation and exports**

| Studies | No. of country | Time-period | Measurement of Innovation | No. of Estimates | Ave Effect Size |
|---|---|---|---|---|---|
| Añón Higón and Driffield (2011) | 1 | 2004 | Mixed | 8 | 0.207 |
| Andersson and Ejermo (2008) | 1 | 2003 | Patent | 4 | 0.165 |
| Bhaduri and Ray (2004) | 1 | 1994–95 | R&D | 8 | 2.275 |
| Beise-Zee and Rammer (2006) | 1 | 1999 | R&D | 6 | 2.263 |
| Bhat and Narayan (2009) | 1 | 2001–2007 | R&D | 5 | 2.804 |
| Bravo-Ortega et al. (2014) | 1 | 1997–2004 | R&D | 4 | 7.06875 |
| Caldera (2010) | 1 | 1991–2002 | R&D | 23 | 0.124 |
| Chadha (2009) | 1 | 1989–2004 | Patent | 2 | 0.067 |
| Filipescu et al. (2013) | 1 | 1994-2005 | Mixed | 6 | 0.209 |
| Franco and Sasidharan (2010) | 1 | 1994–2006 | R&D | 12 | 0.8925 |
| Ganotakis and Love (2011) | 1 | 2004 | Mixed | 8 | 2.658 |
| Girma et al. (2008) | 2 | 1996–2003 | R&D | 12 | 0.202 |
| Goldar (2013) | 1 | 1999-2010 | R&D | 3 | -0.115 |
| Lachenmaier and Wößmann (2006) | 1 | 2002 | Mixed | 17 | 5.544 |
| Montobbio and Rampa (2005) | 9 | 1985–1998 | Patent | 4 | 1.84 |
| Nguyen et al. (2008) | 1 | 2005 | Mixed | 12 | 0.643 |
| Panda et al. (2020) | 67 | 1996-2014 | Technological effort | 6 | 18.807 |
| Pla-Barber and Alegre (2007) | 1 | 2002 | Innovation outcome | 2 | 0.5905 |
| Rasiah et al. (2016) | 1 | 2013 | Innovation capabilities | 1 | 0.628 |
| Rodríguez and Rodríguez (2005) | 1 | 1998-1999 | Mixed | 16 | 2.101 |
| Roper and Love (2002) | 2 | 1991–1994 | Mixed | 12 | 3.193 |
| Sandu and Ciocanel (2014) | 26 | 2006-2010 | R&D | 4 | 8.87 |
| Shin et al. (2016) | 70 | 2000-2007 | Patent | 42 | 1.411 |
| Srholec (2007) | 111 | 2003 | Technological capabilities | 3 | 0.277 |
| Wang and Guan (2009) | 17 | 1991-2005 | Patent | 4 | 1.103 |
| Yang et al. (2004) | 1 | 1996 | Mixed | 23 | 0.092 |
| Zhao and Li (1997) | 1 | 1991 | R&D | 2 | 0.335 |
| **Total** | | | | **249** | |

### *2.3.2.1 Publication Bias and Estimation of Effect Size: PRs & Innovation*

Before performing a meta-regression analysis, there is a need to test the publication trend adopted by authors or journals that relate to the direction of results or significance of coefficients (Neves et al., 2016). Moreover, Stanley (2005) suggests that researchers consider statistically significant results towards specific direction and scale of an effect. Thus, the effect size needs to be further investigated for the possibility of publication bias. Therefore, a *funnel plot* is used to graphically examine this issue. Egger et al. (1997) explain this by using a *funnel plot*, cited by Neves et al. (2016), a scatter plot of effects sizes (in the horizontal axis) against their precision, $\frac{1}{\text{SE}}$ (in the vertical axis). If the graph appears in the shape of an inverted funnel with no asymmetries, then there may be no publication bias. Figure 1 is the funnel plot of the estimated effect sizes against their precision, $\frac{1}{\text{SE}}$ and it presents the impact of PRs on innovation *meta-sample*. Figure 2.1 shows that there is no publication bias towards a certain trend as the figure seems to be symmetric about the "true effect"[10] size.

**Figure 2.1: Funnel plot of the estimated effect sizes against their precision: PRs and innovation**




The graphical presence is not enough to collateral a 'true effect' of the PRs on innovation and owing to graphic inspections may sometimes be

[10] Benos and Zotou (2014) argue that the scatter diagram is symmetrically distributed in the absence of publication bias, with values changing randomly and systematically, around the "true effect".

misleading and may not be accurate. Consequently, the funnel asymmetric test (FAT) is conducted to explore this systematically. FAT is similar to the *funnel plot*, however, with more robustness (Stanley, 2005). Using a simple regression of the effect sizes with respect to the respective standard error (SE), present in the following equation:

$$Effect\ Size_{ij} = \alpha_1 + \alpha_2 SE_{ij} + u_{it} \qquad (2)$$

Where i = 1 ,…..,145 the individual regression estimates reported, and j = 1,….,14 the studies in the meta-database, and $u_{it}$ is the error term. If there is a publication bias, the effect size will be correlated with standard errors that lead to higher standard error and higher value of the effect size as well. To solve the problem of heteroscedasticity, the common practice is to give weights in equation (2) by the standard errors associated with each observation (Stanley, 2005). Consequently, following equation (3) is the weight least square (WLS) of equation (2) by dividing both sides by $SE_{ij}$ that yields more efficient estimates:

$$t_{ij} = \beta_1 + \beta_2 \frac{1}{SE_{ij}} + e_{it} \qquad (3)$$

where $t_{ij}$ is the t-value of the estimated coefficient from estimate i of study j. The intercept, $\beta_1$ ($\beta_1 \neq 0$), and slope, $\beta_2$, coefficients are to be tested if they are statistically different from zero. Nevertheless, there is no issue of heteroscedasticity in the equation (3), and we estimate the equation by ordinary least squares (OLS) regression of the t-statistics with respect to their precision ($\frac{1}{SE_{ij}}$).

Table 2.5 shows that the coefficient is positive and highly significant, which highlights the existence of publication bias in these empirical studies. The possible reason of the publication bias is journalistic trends for publishing papers considering statistically significant results of PRs on innovation.

**Table 2.5: Estimation of equation (3): PRs & innovation**

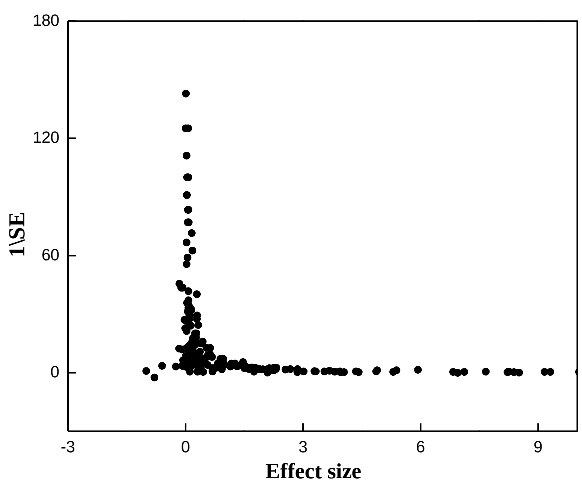
| Variables | Coefficients |
|---|---|
| Precision | 0.06*** |
| | (0.01) |
| Constant | 0.47* |
| | (0.3) |
| Observation | 145 |
| Studies | 14 |
| Log likelihood | -301.467 |

Notes: *, **, *** denote statistical significance at the 0.1, 0.05, 0.01 levels, respectively. Standard errors are in parentheses.

### *2.3.2.2 Publication Bias and Estimation of Effect Size: Innovation & Exports*

As we discussed about the publication bias, we present Figure 2.2, which is the funnel plot of the estimated effect sizes against their precision, 1/SE and it presents the impact of innovation on exports meta-sample. This graph seems to be asymmetric about the "true effect" sizes, and it reveals the existence of publication bias (see Figure 2).

**Figure 2.2. Funnel plot of the estimated effect sizes against their precision: innovation and exports**



As follows, we also estimate the equation (3) by an ordinary least squares (OLS) regression of the t-statistics with respect to their precision ( $\frac{1}{SE_{ij}}$ ). Table 2.6 shows that the coefficient is positive and significant, which shows the existence of publication bias in these empirical studies. The possible reason of the publication bias is journalistic trends for publishing papers considering statistically significant results of innovation on exports, as discussed earlier that the estimates, from the primary studies (27 studies), are having more than 90 % of positive values.

**Table 2.6: Estimation of equation (3): innovation & exports**

| Variables | Coefficients |
|---|---|
| Precision | 0.00006* |
| | (0.00003) |
| Constant | 2.98* |
| | (0.15) |
| Observation | 249 |
| Studies | 27 |

Notes: *, **, *** denote statistical significance at the 0.1, 0.05, 0.01 levels, respectively. Standard errors are in parentheses.

### 2.4 Findings from Meta-Regression Analysis

To analyse the relationship among PRs, innovation and exports, we utilise a simple OLS regression model for MRA, and also employ a random effect maximum likelihood (REML) model to examine the robustness of the coefficients.

#### 2.4.1 MRA Results: PRs and Innovation

Table 2.7 presents the results of the meta-regression analysis. We find a strong evidence that the existing studies' precision coefficient is positive and significant that suggests a positive effect of PRs on innovation. Moreover, the category of country is an important factor in the existing literature. We find that the sign of developing countries' coefficient is negative and highly significant in both the models. This result specifies that the developing countries' PRs policies do not contribute to national innovation such that countries may prefer to imitate external innovation, and that the investment in innovation activity is also very low. On the other hand, in developed countries' the impact of PRs on innovation is positive and significant, this highlights the presence of a robust PRs environment and PRs policy which protect and encourage domestic innovation. Our study suggests that PRs contribute to domestic innovation of developed countries, but the results are not as compelling for developing countries. Surprisingly, the coefficient of the journal is insignificant in all the models. One probable explanation for this result could be very less variation due to the fact that most studies are from journal articles. Our result shows that gross domestic product (GDP) is positive and highly significant in highlighting countries' economic activities and thus plays a major role in countries' innovation activities. The type of countries (developing and developed) and countries' economic activities are consistent part of the effect size variation.

**Table 2.7: Estimation of meta-regression on innovation**

| Variables | Meta-Regression | REML |
|---|---|---|
| Journal | -0.81 | -0.81 |
| | (0.72) | (0.51) |
| Developed country | 1.25* | 1.25* |
| | (0.72) | (0.70) |
| Developing country | -0.68** | -0.68** |
| | (0.32) | (0.31) |
| GDP | 1.24*** | 1.24*** |
| | (0.37) | (0.36) |
| Openness | -0.71 | -0.71 |
| | (0.45) | (0.43) |
| Education | -0.57 | -0.57 |
| | (0.43) | (0.41) |
| Precision | 0.01** | 0.01** |
| | (0.002) | (0.002) |
| Constant | 2.63*** | 2.63*** |
| | (0.84) | (0.82) |
| Observation | 145 | 145 |
| Studies | 14 | 14 |

Notes: *, **, *** denote statistical significance at the 0.1, 0.05, 0.01 levels, respectively. Robust standard errors are in parentheses

### 2.4.2 MRA Results: Innovation and Exports

Table 2.8 presents the results for the meta-regression analysis of the relationship between innovation and exports. We find strong evidence that the existing studies' precision coefficient is positive and significant, which suggest a positive effect of innovation on export success. By the country classification, we find robust evidence that the sign of developed countries' coefficient is positive and highly significant in both the models. This reveals that innovation plays an important role in stimulating developed countries exports. However, developing countries' coefficient is insignificant, highlights that innovation does not contribute to their exports. A probable reason is that, within developing countries, the innovation varies, and some developing countries may be engaged in adaptive R&D for high-technology products that are in the second or third stage of product cycle development. In other words, their innovation falls short of some threshold level. In fact, some countries may even export such products if they are not protected by patents or are off-patents in the international markets.

The coefficient of journal is insignificant in all the models. Reason for the result could be very less variations since most studies are from journal articles with less than 10% of total publications as working papers and conference proceedings. Our result shows that GDP is positive and significant highlighting that countries' economic activities play a major role in exports performances. We also find that firms' profitability enhances developed countries' export performances. Interestingly, we find that countries' size of the firm, as measured by net fixed assets in most of the primary studies, positively stimulate export performance.

**Table 2.8: Estimation of meta-regression analysis on Exports**

| Variables | All studies | | Developed countries studies | | Developing countries studies | | Mixed studies | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Precision | 0.0001*** | 0.00008** | 0.00007*** | 0.00007*** | -0.02 | -0.02 | -0.12** | -0.12*** |
| | (0.00001) | (0.00003) | (0.00001) | (0.00003) | (0.02) | (0.02) | (0.03) | (0.03) |
| Country level | 0.33 | 0.33 | 0.61 | 0.61 | 1.27 | 1.27 | | |
| | (0.55) | (0.52) | (0.55) | (0.55) | (0.91) | (0.91) | | |
| Journal | 0.61 | 0.61 | -0.77 | -0.77 | 0.89 | 0.89 | -0.12 | -0.12 |
| | (1.05) | (0.81) | (0 .64) | (1.19) | (1.34) | (1.34) | (1.75) | (1.75) |
| GDP | 1.34 | 1.34* | 0.53 | 0.53 | | | | |
| | (0.89) | (0.73) | (1.47) | (1.17) | | | | |
| Size | 0.29 | 0 .29 | -0.42 | -0.42 | | | 9.03*** | 9.03*** |
| | (0 .45) | (0.45) | (0.45) | (0.5) | | | (2.06) | (2.06) |
| Profit | 0.89** | 0.89* | 1.82** | 1.82** | 0.39 | 0.39 | | |
| | (0.44) | (0.47) | (0.66) | (0.59) | (0.69) | (0.69) | | |
| distance | 0.21 | 0.21 | 2.2 | 2.2* | | | 2.3** | 2.3** |
| | (0.94) | (0.75) | (1.69) | (1.33) | | | (1.16) | (1.16) |
| Constant | 1.5 | 1.5 | 2.9 | 2.9** | 0.74 | 0.74 | 2.38* | 2.38* |
| | (1.03) | (0.75) | (0.49) | (1.1) | (1.59) | (1.59) | (1.39) | (1.43) |
| Observation | 249 | 249 | 146 | 146 | 48 | 48 | 55 | 55 |
| Studies | 27 | 27 | 15 | 15 | 8 | 8 | 4 | 4 |

Notes: *, **, *** denote statistical significance at the 0.1, 0.05, 0.01 levels, respectively.
Robust standard errors are in parentheses.

## 2.5 Conclusion

This dissertation undertakes an extensive review of literature on the impact PRs on innovation and then exports. The review is further strengthened by meta-regression analysis to understand the sensitivity of results of empirical studies to data, the period of study and most importantly to the level of economic development of sample countries.

Our approach to the synthesis of narrative reviews and meta-regression analysis reveals that PRs protection plays an important role in determining domestic innovation across countries. With concern to the type of countries, we find strong evidence that PRs policy encourages developed countries' domestic innovation; notwithstanding, it dampens developing countries' domestic innovation. This finding reflects the present PRs system has a distribution bias, in which a strong PRs regime favours the expansion of innovation in high-income countries.

We find that innovation determines exports success across countries. By the form of countries, we find strong evidence that developed countries' domestic innovation enhances their exports; notwithstanding, for developing countries, innovation does not contribute to their exports. It indicates that within developing countries, the level of innovation efforts varies, and concomitantly these countries are unable to translate such efforts into exports. The results are also not as compelling for developing countries owing to the limited variation in their innovation efforts.

The present studies agree that minimum economic development needs to be attained for the PRs to contribute towards innovation and economic growth. Further, we suggest that there is divergence in innovation efforts among middle-income countries and concomitantly their inability to translate these same efforts in exports. This divergence in the innovative efforts and its outcome remains unstudied in the present literature. Based on such research gaps, we propose to study the impact of PRs protection on the technological efforts of a country and its contribution to high-technology exports at both aggregated and disaggregated level in the next chapters.

# Chapter 3

# Patent Protection, Technological Efforts, and Exports: An Empirical Investigation

## 3.1 Introduction

Technology has been recognized as an important component of the international competitiveness of countries. The neo-technology theories underline the role of the technology gap, particularly in determining the trade pattern across countries (Posner, 1961; Vernon, 1966; Krugman, 1979). Motivated to fill the gap and become internationally competitive, developing countries make extensive technological efforts that are expected to contribute to their export performance. The contribution of high-technology exports in economic growth has been empirically verified by various studies (Srholec, 2007; Falk, 2009). The export performance is enhanced when developing economies are able to move beyond trade in primary and low technology goods to high-technology products (Lall, 2000; Srholec, 2007). The existing evidence on the role of technology in developing countries exports is mixed. For instance, in the case of Brazil, Willmore (1992) finds that research and development (R&D) expenditures have no significant effect on its exports, whereas Kumar and Siddharthan (1994) suggest that technology plays an important role in explaining the export performance of Indian enterprises. Moreover, Shin et al. (2016) argue that, within developing countries, the technology levels vary and lead to a complex picture. Some developing countries may be engaged in adaptive R&D for high-technology products that are in the second or third stage of product cycle development. In fact, some countries may even export such products if they are not protected or are off-patent in the international markets.[11] Another country may have evolved up the technology ladder in a few sectors to actually produce and export patented products that may be in the first stage of their product cycle development.[12]

With the aim of enhancing economic growth through technological progress, policymakers undertake initiatives including policy tools like patent protection. In particular, World Trade Organization (WTO) member developing countries made changes in patent rights (PRs) after the passage of the agreement on Trade-Related Intellectual Property Rights (TRIPS) in 1995. Specifically, PRs have been internationalized with TRIPS, as developing countries were required to meet minimum standards on various intellectual property rights. Such changes were expected to bring benefits to the developing countries by creating the incentive structure essential for knowledge generation and diffusion, technology transfer, and private investment flows (Braga, 1995; Fink and Maskus, 2005). According to the 'promotion channel', PRs affect innovation in an economy and concomitantly its economic growth. Empirical studies, however, seem to show that the impact of strong PRs on innovation as well as on the economic growth of developing countries is predominantly negative (Nogues, 1993; Watal. 2000; Kumar, 2003). These studies conclude that developing countries are primarily dependent on imitation of foreign technologies for their economic growth, and strong PRs negatively affect such innovations (Sharma, 2012). A few studies, however, conclude that the innovativeness of developing countries has reached a stage where it can be positively affected by strong PRs. It appears from the results that not all developing countries' domestic innovation responds to patent rights in a similar way (Kim et al., 2012; Sweet and Maggio, 2015). The existing studies either explore the impact of PRs on economic growth, or on innovativeness

[11]India's exports of generic drugs provide an example of such exported products.
[12]Chinese dominance in the patenting and exporting of solar panels is a case in point.

through R&D and patenting.[13] It is not evident in these studies how the changes in innovativeness translate into economic growth. A second set of literature explores the impact of PRs on high technology exports to developing countries from developed countries as a potential source of technology spillovers and hence growth (Ivus, 2010 and 2015). In this essay, we propose to study the impact of PRs on the technology efforts of a country and its contribution to high-technology exports. We combine the technology efforts made by countries and their contribution to high-technology exports in order to provide a source and mechanism through which strong PRs contribute to economic growth, as such a channel remains unexplored in the current literature.

In order to capture the innovation of countries, existing studies use either input based measures like R&D expenditure or output based proxies like patents. However, these measures *cannot* capture the extent of technology efforts made by developing countries. Within the developing country world, as mentioned earlier, different variants of 'effort' may exist and hence this study utilises principal component analysis (PCA) to construct a technology effort index, including both input and output indicators of innovation. Exports are defined as high technology exports as a percentage of manufactured exports. We utilise high-tech exports because high-tech products are used to represent the technological intensity of exports (Srholec, 2007). In the manufacturing industries, the effect of patents on exports is usually the strongest and tends to play a leading role in such industries' patenting activities (Balasubramanian and Sivadasan, 2011). We use a panel dataset consisting of 67 countries for the period 1996-2014.[14] The empirical results demonstrate that a source country's PRs index

[13]See for instance, Grossman and Helpman, 1993; Diwan and Rodrik, 1991; Gould and Gruben, 1996; Ginarte and Park, 1997; Park, 2008; Chen and Iyigun, 2011.

[14] The choice of the dataset is based on the introduction of TRIPs and the availability of data.

influences its technology efforts. Furthermore, the technological efforts of countries increase the likelihood of high technology exports.

This essay contributes to the existing literature on PRs, technology, and trade in the following ways. First, this study applies PCA to construct the technology effort index, including both input and output indicator of innovation. Second, this study highlights an incremental perspective on an existing channel through which countries gain from PRs, as it influences the technology effort of countries that further stimulates their exports. Lastly, we approach the problem from the source country's perspective in order to introduce variations in terms of host country factors. Since developing countries have implemented patent policy changes to comply with TRIPs, a study that focuses on such economies is essential.

The rest of the essay is organised as follows. The next section sets the background by reviewing the existing evidence on technological efforts, PRs, and exports and by describing their inter-relationship. Section 3.3 provides details on the variables, data sources and the model. The empirical results are presented in section 3.4. Section 3.5 presents the discussion of the empirical results. Section 3.6 provides robustness checks of the results obtained from the benchmark model. Section 3.7 summarises and concludes the paper.

## 3.2 Previous Literature

Endogenous growth theory postulates that technology adaptation, innovation, and imitation are the key factors for the technological progress of a country (Romer, 1990; Hofmann, 2013). Such progress contributes to the economic growth of an economy by determining its international competitiveness (Vernon, 1966; Lindbeck, 1981). Studies underscore that innovation and new technology adoption enable firms to enter foreign markets and enhance their export performances in developed countries (Basile, 2001; Dhanaraj and Beamish, 2003). In the context of developing countries, studies find mixed evidence regarding the role of technology in explaining trade performance. Dasgupta and Siddharthan (1985) suggest that goods of Indian exports largely consist of low technology. Kumar (1990) observes that R&D intensity and technology imports do not significantly influence the export performance of Indian industries. Moreover, in the case of Brazil, Willmore (1992) finds that R&D expenditures have no significant effect on its exports. However, in the case of India, other studies do attribute the role of technology in determining the export performance of firms (Bhaduri and Ray, 2004; Bhat and Narayanan, 2009). We find that these studies use different measures to operationalize technological progress; for instance, technology is determined by using technological capabilities (Bhaduri and Ray, 2004) and technological efforts (Bhat and Narayanan, 2009). We note that these measures are limited as they capture either input or output in the knowledge production function,[15] and these measures do not capture the extent of technology efforts made by developing countries. Within developing countries, as mentioned earlier, different variants may exist. Thus, we propose to construct the index of technology efforts using both input and output indicators of innovation to analyse the technology efforts made by developing country – efforts that contribute towards its exports (which will be discussed in detail later). Earlier, a technology efforts index was constructed by Lall (2003), an offshoot of the widely discussed and researched the concept of technological capability.[16] Technology efforts consist of a broad spectrum of production engineering, design, and research work by firms, and such efforts can be manifested in their production efficiency and export activity. The technology efforts of a country mostly

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[15]Griliches (1990) establishes R&D as an input into the knowledge production function that leads to output in the form of patents.

[16]Kim (1997) defines technological capability as "the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt and change existing technologies" (p. 4). Capability can be grouped under three broad headings, such as physical investment, human capital, and the technological effort of a country.

depend on the dynamism in technology development, particularly in terms of national policies to improve factor markets that influence the incentive environment (Lall, 1992).

PRs protection is an institutional factor that supports the technological efforts of a country.[17] As suggested in the promotional channel of gains from PRs, strong protection is expected to stimulate domestic innovation, whereby a firm may invest more in R&D in the expectation that it will profit from the newly developed product or process. Moreover, as countries with patent protection develop technology, such protections further stimulate domestic innovation (Grossman and Helpman, 1993; Diwan and Rodrik, 1991; Gould and Gruben, 1996; Ginarte and Park, 1997; Park, 2008; Chen and Iyigun, 2011). According to the prospect theory, a stronger PRs system provides incentives to commercialize and organise the market more effectively for innovation (Kitch, 1977). PRs have played a major role in diffusing knowledge-based or high technology products in the international market (Fink and Maskus, 2005).

Interestingly, PRs protection not only influences the technological efforts of a country but also has a bearing on trade among countries. Many theoretical studies conclude that there is an ambiguous relationship between strong PRs of destination countries and the trade flows of source countries because of two opposing effects; namely, market expansion and market power effects (Taylor, 1993; Maskus and Penubarti, 1995; Smith, 2001). Strong PRs in the destination country, through a 'market expansion effect', allow firms to increase the market by reducing imitation. On the other hand, strong PRs may result in a 'market power effect' that induces the firm to restrain their production. The market power effect reduces the elasticity of demand for a firm's product, which would ordinarily induce the firm to export less of its patentable product (Taylor, 1993; Maskus and Penubarti,

[17] Incentives, institutions, and factor market are the major determinants of the technology development of a country (Lall, 1992, 1998).

1995; Smith, 2001). Most of these studies highlight the developed countries' perspective, with developing countries as a net consumer of new products. The impact of a source country's PRs on its export through the stimulation of technological efforts remains unexplored in the literature. Briggs and Park (2014) find that PRs play an important role in strengthening a local firm's position in technology trade. Shin et al. (2016) study the interaction effect of a destination country's PRs protection and a source country's level of technology on exports. They argue that foreign PRs influence the marginal contribution of technology to export performance, and the innovative capacity of the source country influences the relationship between PRs and trade. They find that the effect of an importer's patent rights on a source country's exports is highly dependent on the exporting country's level of technology. When an importing country's level of patent protection rises, the marginal net effect of technology on exports falls.

These studies do not examine the influence of the source countries' PRs protection on their technological efforts. From the promotional channel of gains from PRs, as discussed earlier, strong protection is expected to stimulate domestic innovation. Therefore, it is of interest to study the relationship between PRs and exports conditioned by the technological efforts of the source country. Moreover, according to Lall (1998), "a great deal of technological effort in the early years was based on copying foreign technologies, and the countries adopted a fairly relaxed attitude to intellectual property protection. As the industrial sectors matured and approached nearer to technological frontiers, local R&D needed greater protection; in addition, pressures for stronger intellectual property regimes grew internationally" (p. 235).

From the above discussions, we now present two hypotheses regarding the effects of technological efforts and patent protection on exporting across countries:

**H1**: *Source countries' PRs protection influences countries' technological efforts positively*.

**H2**: *The technology efforts of a country influence its high technology exports positively*.

## 3.3. Method

### 3.3.1 Model Specification

For empirical purposes, we propose to use a panel data technique to analyse the relationship among PRs, technological efforts, and exports.

This study considers the following equations:

$$\mathrm{TE_{it}} = \mathrm{C_1} + \beta_{11}\mathrm{PR_{Sit-1}} + \beta_{12}\mathrm{TII_{Sit-1}} + \beta_{13}\mathrm{Size_{Sit}} + \beta_{14}\mathrm{Edn_{Sit-1}} + \beta_{15}\mathrm{Capital_{Sit}} + \beta_{16}\mathrm{OPN_{Sit-1}} + \mathrm{u_{it}} \quad (1)$$

$$\mathrm{EXP_{it}} = \mathrm{C_1} + \alpha_{11}\mathrm{TE_{Sit-1}} + \alpha_{12}\mathrm{GDP_{Dit-1}} + \alpha_{13}\mathrm{OPN_{Dit-1}} + \alpha_{14}\mathrm{EXR_{Sit-1}} + \alpha_{15}\mathrm{PR_{Dit-1}} + \alpha_{16}\mathrm{TE_{Sit-1}} * \mathrm{PR_{Dit-1}} + \epsilon_{\mathrm{it}} \quad (2)$$

Where i denotes country (i= 1, 2,3, ……*n*), and t time (in years). Subscript D stands for destination country and S for source country in equations 1 and 2. As dependent variables, TE denotes the technology efforts index and EXP represents the high technology exports as a percentage of manufactured exports. As independent variables, we build on the literature to introduce control variables and include an index of patent rights, which is the prime factor for the study. The detailed reasons for introducing these variables are given later along with the construction of variables. Continuing with our definitions, PR refers to the patent rights (PRs) index (as used before) and TII is the countries' technological infrastructure index. Size refers to government consumption expenditure as a percentage of GDP, Edn denotes the education as the secondary school enrollment (% gross), Capital denotes the gross capital formation (% of GDP), OPN denotes the trade openness index, GDP denotes the gross domestic product per capita growth (% annual), and EXR denotes the official exchange rate per unit U.S. dollars (local currency per US$, period average).

While estimating equations 1 and 2, we may encounter the problem of endogeneity[18] particularly with respect to TE, PR and EXP, as the literature suggests. Existing studies employ different approaches to address the problem of endogeneity by using either instrumental variables or lagged independent variables. We use lag variables because of the lack of reliable instruments. In the estimations, both fixed effect (FE) and random effect (RE) regression techniques are applied to estimate the coefficients. Finally, the choice between FE and RE technique is based on the Hausman (1978) specification test. We estimate both equations (1) and (2) for a full sample of our countries, [19] and then estimate them by subgroups of high-income and middle-income countries, as based on the World Bank (2016) classification of economies.[20] These split samples help us measure the varying effects of technological efforts, exports, and PRs by income group.

### 3.3.2 Variable Constructions

The description along with the rationale for the independent variables introduced in equations 1 and 2 is as follows:

Technology Effort Index: This study computes a technology efforts (TEs) index by principal component analysis (PCA).[21] Five variables are included

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[18] An endogeneity problem occurs when the right-hand side variables and the error term is correlated. There are at least three basic sources of endogeneity, such as simultaneity, model misspecification, and measurement error.
[19] 67 countries are included in this study based on data availability.
[20]Middle-income economies are those whose gross national income (GNI) per capita is more than $1,026 but less than $12,475 and High-income economies are those whose GNI per capita is $12,476 or more (World Bank, 2016).
[21] Principal component analysis (PCA) is a statistical procedure which converts an original set of observations, possibly correlated variables, into a substantially smaller set of uncorrelated variables that represents most of the information in the original set of variables (Hotelling, 1933). Moreover, PCA reduces the dimensionality of the variable set and decompose the total variance.

to construct the index where three of them represent input indicators: R&D expenditure as % of GDP, researchers in R&D per billion population, number of patent application by non-residents. Non-resident fillings represent inward technology transfer, hence, are categorized as an input indicator. The remaining two variables represent output indicators: the number of the patent application by residents and the number of published scientific and technical journal articles. The last three variables (publications, non-resident patents, and resident patents) are standardized by real GDP to adjust for the economic size of a country. The TEs index ranges from 0 to 5.37 where higher values indicate intensive innovation activity. The average of TEs index of high-income and middle-income countries are 1.9 and 0.35 and maximum value of TEs index are 5.37 and 1.99 respectively (for factor scores see Appendix A) Scientific and technical journal articles and patents capture output produced due to investments made in R&D.[22] 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 and Planta, 1996). There exists a complementary relationship among foreign patenting, exports, FDI, and licensing. Consequently, a foreign patent filing helps capture new technologies introduced to the domestic market (Branstetter, 2004; Lerner, 2002).

This study uses an index based on Ginarte and Park (1997), Park (2008), and Property Rights Alliance (2016) to quantify the level of patent rights protection (PRs) across countries.[23] In equation (1), we use the source country's PRs index and in equation (2), we use the weighted average of

[22] Patents, though frequently viewed as output indicators can also be viewed as input indicators as data in patents are used by subsequent inventors for information (Griliches 1990).

[23]Park and Ginarte (1997) develop the PRs index that indicates the strength of PRs protection in each country. The index, range in value from 0 to 5, higher values of the index reflecting stronger levels of protection. Further, Park (2008) extends the index to more countries and longer time. This study also uses property right alliance (2016) PRs Index for few countries due to the unavailability of data of Park (2008) PRs index.

destination countries' PRs index as the PRs protection measure, where the destinations are a source country's top 20 trading partners, as measured by export share.

Technological Infrastructure Index (TII): Following Archibugi and Coco (2004), this study builds a technological infrastructure index using three different indicators of infrastructure: internet, telephone, and electricity. These are not only basic infrastructure for economic and social life but also for access to knowledge. We use internet penetration as individuals using the internet (% of population), telephone penetration as fixed telephone subscriptions (per 100 people), and electricity penetration as percent of the population with access to electricity. For each country, each of these three variables is standardized using following technique (Lall, 2003 and Archibugi and 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 three standardized variables to construct the TII index.[24] Technological infrastructure supports the technology efforts of firms over a broad spectrum of production, design and research work (Lall, 2000, 2003).

Secondary school enrollment (% gross) is assumed to capture the inputs into technological efforts of a country (Lall, 2000). Gross capital formation (% of GDP) is used to capture the role played by physical capital in developing an innovating economy (Funke and Strulik, 2000). This paper has taken the growth rate of GDP per capita (% annual) to measure the economic activity of countries (Barro, 1996). GDP is also used to proxy the overall market size, which affects incentives to patent (Allred and Park, 2007). Trade

[24] There are only three components to construct the index and one component (electricity) has the same maximum value across countries, such that it yields very low variance in that component. Hence, we did not utilise the PCA method to construct the TII index because PCA is required to decompose the total variance of each variable.

openness (OPN) is equal to exports plus imports divided by GDP. Cross country studies tend to find a positive association between trade openness and technology adoption (Caselli and Coleman, 2001; Comin and Hobijn, 2004) or between trade openness and R&D investments (Lederman and Maloney, 2003). Government Size as measured by government consumption expenditure as a percentage of GDP can capture public goods inputs for private production and can create a productive link between endogenous growth and the government sector (Barro, 1990). The exchange rate measure used is essentially the relative price of tradable to non-tradable products, which can have a potentially strong impact on the incentive to allocate resources between sectors producing such goods. It is also a measure of real competitiveness, as it captures the relative prices, costs, and productivity of one specific country vis-à-vis the rest of the world (Dornbusch, 1976; Auboin and Ruta, 2013).

### 3.3.3 Data

Table1 provides variable definitions, some descriptive statistics, and data sources. This study uses panel data analysis to quantify the effect of PRs protection on technology effort and in turn its influence on exports. The total number of observations is 335, as there are 67 countries and 5 periods. Following Thompson and Rushing (1999), we have taken data as a five year average during 1996-2014.

Table 3.1 shows that countries' average technology efforts index is 1.2. Average high technology exports as a percentage of all manufactured exports is 13.83. Moreover, the average PRs index of the source country is 3.68 (out of 5). The average destination country's PRs protection is 4. Table 3.2 shows the correlation matrix, indicating that the source countries' PRs protection and technology infrastructure are positively correlated with technology effort. Moreover, technology effort and PRs are also positively correlated with exports. Table 3.3 shows the average value of technology efforts index, PRs and high technology exports by period. In 1996, the average technology effort indices of the full sample, high income, and middle income sample, are 0.7, 1.13, and 0.18 respectively. In 2014, the average technology effort index values of these corresponding samples have increased to 1.57, 2.44 and 0.49, respectively.

The figures below plot the source countries' patent rights index against their technology efforts. In general, we see a positive correlation, technology effort is typically higher in high income countries than in middle income countries.

As expected, there is a closing of gap between high income and middle income countries' average PRs values. A possible justification for this is that the year 2000 was the deadline to comply with TRIPs for middle income countries, and most of them were in transition. Therefore, 2000 can be treated as the initial year for measuring the effects of PRs, as also suggested by Shin, et al. (2016).

## Table 3.1: Variables definition, basic statistics and data sources

| Variable Name | Definition | Mean | Std. Dev. | Min | Max | Data Source |
|---|---|---|---|---|---|---|
| **TE** | Technology effort index | 1.2 | 1.16 | 0 | 5.5 | WDI WIPO |
| **EXP** | High technology exports as a percentage of manufactured exports | 13.83 | 13.14 | 0 | 72.62 | UN Comtrade, WITS |
| **$PR_{St-1}$** | Strength of patent protection in source country | 3.68 | 0.91 | 1.07 | 5.52 | Park (2008) and Property Alliance(2016) |
| **$PR_{D\ t-1}$** | Weighted average of destination countries' IPR index with top 20 trading partners (based on export share) | 4.00 | 0.35 | 2.84 | 4.71 | Park (2008) |
| **$TII_{t-1}$** | Technology infrastructure index | 0.56 | 0.23 | 0.001 | 0.98 | WDI |
| **$GDP_{D\ t-1}$** | Weighted average of destination countries' GDP per capita growth (annual%) of top 20 trading partners | 2.52 | 0.76 | 0.96 | 7.64 | WDI |
| **Size** | Government consumption expenditure as a percentage of GDP | 59.52 | 12.18 | 0 | 102.2 | WDI |
| **$Edn_{t-1}$** | School enrollment, secondary (% gross) | 89.07 | 26.83 | 0 | 156.85 | WDI |
| **Capital** | Gross capital formation (% of GDP) | 23.95 | 5.73 | 0.29 | 47.32 | WDI |
| **$EXR_{t-1}$** | The official exchange rate per unit U.S. dollars (local currency per US$, period average) | 191.12 | 1000.2 | 0 | 9495.9 | WDI |
| **$OPN_{S\ t-1}$** | Trade openness is exports plus imports divided by GDP of source country | 0.86 | 0.99 | 0 | 8.22 | UN Comtrade, WITS,WDI |
| **$OPN_{D\ t-1}$** | Openness is the weighted average of destination countries' trade openness of top 20 trading partners | 0.73 | 0.16 | 0.44 | 1.27 | UN Comtrade, WITS,WDI |

**Notes:** World Development Indicator (WDI), World Bank. World Intellectual Property Organization (WIPO). World Integrated Trade Solution (WITS), World Bank.

**Table 3.2: Correlation matrix**

| Variables | TE | PRs_S $_{t-1}$ | TII $_{t-1}$ | Size | Edn $_{t1}$ | capital | OPN_S $_{t-1}$ | Exports | PRs_D $_{t-1}$ | TE*IPR | Gdp_D $_{t-1}$ | Opn_D $_{t-1}$ | Exr $_{t-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TE** | 1 | | | | | | | | | | | | |
| **PRs_S $_{t-1}$** | 0.64 | 1 | | | | | | | | | | | |
| **TII $_{t-1}$** | 0.80 | 0.68 | 1 | | | | | | | | | | |
| **Size** | -0.53 | -0.38 | -0.44 | 1 | | | | | | | | | |
| **Edn $_{t-1}$** | 0.66 | 0.67 | 0.76 | -0.42 | 1 | | | | | | | | |
| **capital** | -0.06 | -0.02 | -0.15 | -0.37 | -0.07 | 1 | | | | | | | |
| **OPN_S $_{t-1}$** | -0.04 | 0.05 | 0.06 | -0.03 | 0.05 | 0.045 | 1 | | | | | | |
| **Exports** | 0.22 | 0.18 | 0.16 | -0.32 | 0.13 | 0.002 | -0.013 | 1 | | | | | |
| **PRs_D $_{t-1}$** | 0.44 | 0.53 | 0.58 | -0.30 | 0.50 | -0.068 | 0.161 | 0.129 | 1 | | | | |
| **TE*IPR** | 0.70 | 0.64 | 0.83 | -0.48 | 0.65 | -0.213 | 0.005 | 0.171 | 0.517 | 1 | | | |
| **GDP_D $_{t-1}$** | 0.05 | 0.04 | -0.03 | -0.12 | 0.09 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 1 | | |
| **OPN_D $_{t-1}$** | -0.05 | 0.11 | 0.06 | 0.17 | 0.09 | 0.11 | 0.08 | -0.01 | 0.21 | -0.07 | -0.08 | 1 | |
| **Exr $_{t-1}$** | -0.12 | -0.13 | -0.16 | -0.01 | -0.14 | 0.09 | -0.06 | -0.03 | -0.06 | -0.12 | -0.01 | 0.07 | 1 |

**Table 3.3: Average value of TI, PRs and exports**

| | TE | | | PRs | | | Exports | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | All | HI | MI | All | HI | MI | All | HI | MI |
| 1996 | 0.7 | 1.13 | 0.18 | 3.15 | 3.09 | 2.2 | 11.6 | 13.98 | 8.65 |
| | (0.1) | (0.14) | (0.07) | (0.14) | (0.1) | (0.15) | (1.56) | (2) | (2.4) |
| 2000 | 1.03 | 1.65 | 0.26 | 3.64 | 4.18 | 2.95 | 14.96 | 16.8 | 12.61 |
| | (0.12) | (0.15) | (0.07) | (0.11) | (0.08) | (0.14) | (1.81) | (2.05) | (3.17) |
| 2005 | 1.24 | 1.98 | 0.33 | 3.87 | 4.39 | 3.24 | 15.01 | 17.02 | 12.51 |
| | (0.14) | (0.17) | (0.07) | (0.09) | (0.06) | (0.1) | (1.74) | (1.87) | (3.12) |
| 2010 | 1.45 | 2.29 | 0.46 | 3.96 | 4.42 | 3.39 | 14.23 | 15.93 | 12.14 |
| | (0.15) | (0.18) | (0.07) | (0.08) | (0.07) | (0.9) | (1.57) | (1.68) | (2.83) |
| 2014 | 1.57 | 2.44 | 0.49 | 3.96 | 4.41 | 3.42 | 13.37 | 14.55 | 11.85 |
| | (0.16) | (0.18) | (0.09) | (0.08) | (0.06) | (0.9) | (1.3) | (1.3) | (2.46) |

Note: Numbers in parentheses are standard deviations.

Figures 3.2 and 3.3 plot the relationship between PRs protection and technological efforts of income groups. While there is a positive trend in both samples, efforts are relatively lower in middle-income countries as compared to high-income countries.

**Figure 3.1: All countries: PRs protection and TEs**

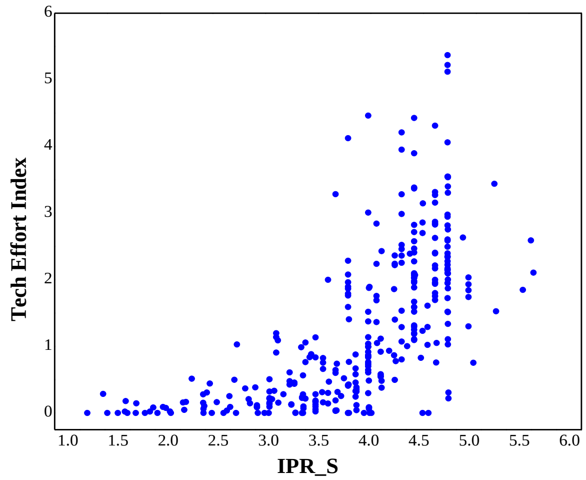



**Figure 3.2: High-income countries: PRs protection and TEs**

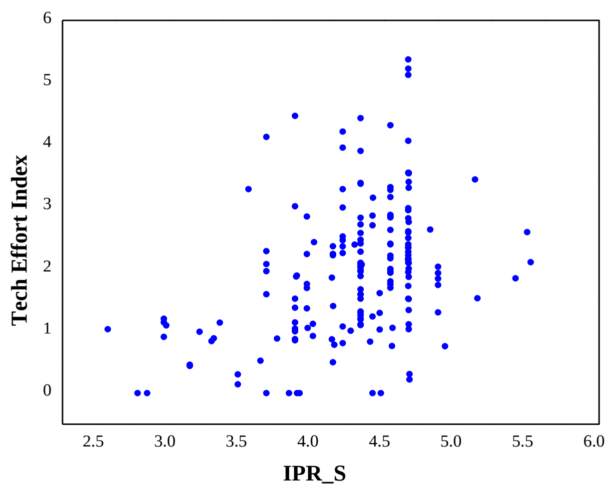
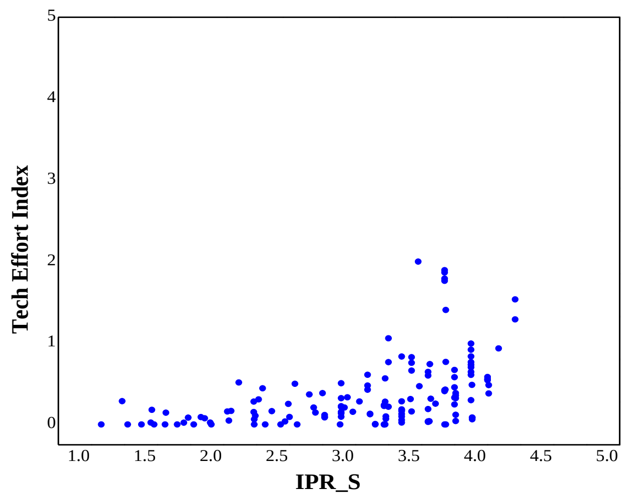


**Figure 3.3: Middle-income countries: PRs protection and TEs**




## 3.4 Empirical Results

Tables 3.4 and 3.5 present results for all our countries, and by subgroups: high income and middle income countries. We report both FE and RE estimates, though our discussion is based on the model selected as per the Hausman test. Moreover, we first include only key variables of interest and later include control variables. We have performed time-fixed effects tests in all the specifications to check for year specific effects.

### 3.4.1 Empirical Results of Technology Efforts Equation

Table 3.4 reports the empirical results of the technology effort equation (i.e. equation 1) and further our discussion is based on FE estimations that are consistent as per the Hausman test. The result shows that the coefficient of PRs index is positive and statistically significant at conventional levels for all the models. In the case of high income and middle income country groups, the coefficient is significant. The coefficient estimate indicates that strong PRs protection stimulates domestic technological efforts and does indeed spur innovative activities in the source country. Furthermore, the empirical result indicates that technological infrastructure index (TII) is a positive and significant determinant of source countries' technological efforts. The results for both PRs and TII variables remain unchanged when the control variables are added, except for the PRs variable under RE estimation for high-income countries. This can be due to the high level of PRs and limited variation in patent rights in the high-income country group.

Trade openness positively influences countries' technological efforts in high income countries as well. The coefficient of government size is positive and significant for middle income countries, highlighting that productive role of government in enhancing middle-income countries' technological efforts. In terms of other control variables, we do not find significant influences of the other factors considered. One possible explanation for this could be that, as some of the literature (Lall, 2000 and 2003) suggests, incentives and infrastructure are the key significant contributors towards technological efforts undertaken in a country. Surprisingly, the coefficient of education is insignificant in all the equations. One probable explanation for this result could be the limited variation in this measure for high-income countries as these countries have achieved almost 100% secondary school enrollment. Moreover, the average value is 89% after including the middle-income countries, which is also very high, albeit with limited variation as well. A more refined proxy for higher education's availability, cost, and accessibility may be a more appropriate variable to try to capture the human capital. Moreover, we have tried to introduce control variables one by one (in different order) instead of in one go and did not find any variation in the results.

**Table 3.4: Results of technology effort equation**

| Dependent Variable: Tech Efforts Index | All countries | | | | High Income | | | | Middle Income | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FE | | RE | | FE | | RE | | FE | | RE | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $PR\_S_{t-1}$ | 0.05 | 0.05 | 0.08* | 0.10* | 0.32** | 0.13 | 0.31** | 0.28** | 0.08** | 0.09** | 0.09*** | 0.09*** |
| | (0.05) | (0.06) | (0.05) | (0.06) | (0.15) | (0.15) | (0.13) | (0.13) | (0.03) | (0.04) | (0.03) | (0.01) |
| $TII\_S_{t-1}$ | 2.99*** | 2.27*** | 3.36*** | 3.13*** | 3.14*** | 2.11*** | 3.36*** | 3.08*** | 1.2*** | 1.19** | 1.15*** | 1.35*** |
| | (0.38) | (0.46) | (0.3) | (0.35) | (0.57) | (0.65) | (0.50) | (0.55) | (0.3) | (0.5) | (0.29) | (0.39) |
| Size_S | | (0.0008) | | -0.01*** | | 0.01 | | -0.02 | | 0.01* | | -0.006 |
| | | (0.01) | | (0.007) | | (0.02) | | (0.01) | | (.008) | | 0.004 |
| $Edn\_S_{t-1}$ | | -0.0009 | | -0.001 | | -0.0004 | | 0.0002 | | 0.0007 | | 0.0003 |
| | | (0.002) | | (0.002) | | (0.003) | | (0.003) | | (0.001) | | (0 .001) |
| Capital_S | | -0.01 | | -0.01** | | 0.01 | | 0.005 | | 0.002 | | -0.007 |
| | | (0.008) | | (.008) | | (0.01) | | (0.01) | | (0 .008) | | (.006) |
| $OPN\_S_{t-1}$ | | 0.59*** | | -0.02 | | 1.13*** | | 0.16 | | 0.01 | | -0.01 |
| | | (0.18) | | (0.07) | | (0.35) | | (0.24) | | 0.16 | | (0.04) |
| Constant | -0.52** | -0.23 | -0.85 | 0.85 | 1.51*** | -1.96 | -1.63** | -0.51 | 0.29*** | -1.4 | 0.31*** | 0.2 |
| | (0.20) | (0.89) | (0.19) | (0.65) | (.54) | (1.92) | (0.51) | (1.58) | (0.11) | (0 .6) | (0.11) | (0.41) |
| Hausman test | 10.02*** | 26.31*** | | | 0.89 | 22.99*** | | | 0.58 | 67.1*** | | |
| | (0.00) | (0.00) | | | (0.64) | (0.00) | | | (0.7) | (0.00) | | |
| $R^2$ | 0.34 | 0.41 | 0.34 | 0.36 | 0.40 | 0.47 | 0.40 | 0.42 | 0.35 | 0.38 | 0.35 | 0.31 |
| Observation | 252 | 229 | 252 | 229 | 140 | 136 | 140 | 136 | 112 | 93 | 112 | 93 |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

### 3.4.2 Empirical Results of Exports Equation

The empirical results of the export equation are presented in Table 3.5, and the discussion is based on RE estimations following the Hausman test. The technology effort index is highly significant with a positive sign in high income countries. This result implies that countries' technological efforts increase the likelihood that high income countries will export high technology products. The destination countries' PRs index is positively significant in all the samples and estimation models. Thus, this result indicates patent rights help attract exports from other countries – that the expansion and enforcement of global PRs play a significant role in the economic development of economies by helping to draw high technology products to both high-income and middle-income countries.

We also controlled for an interaction effect, following Shin et al. (2016), to capture the combined effects of the technological efforts of a source country and the patent rights (PRs) of destination countries on the exports of source countries. We have discussed in our literature review that there is an ambiguous relationship between the PRs of destination countries and the trade flows of source countries. This is due to two opposing effects, such as the market expansion effects and market power effects. Moreover, Shin et al. (2016) argue that if a source country has a high level of technology, then stronger foreign PRs protection affects the incentive of exporters to enhance the volume of exports. Therefore, we likewise examine the interaction effect between source countries' technological effort and destination countries' PRs on exports. We find in our case that interaction coefficient is negatively related to exports for the high income countries; that is, holding technological efforts (TEs) constant, a higher level of destination PRs is associated with a lower volume of source exports. Thus, in our case, what we seem to reveal is that the market power effect of destination patent rights dominate the market expansion effects on exports in the specific case where the exportable product was propelled by higher technological efforts. To put it another way, controlling for other factors, the greater the technological efforts a country invests, the lower the exports in response to stronger patent protection abroad (i.e., in the top 20 destination markets). The intuition is that the top 20 destination markets are relatively large. Opportunities for exploiting higher prices appear to be greater in such markets. Thus, for greater technologically developed products (i.e., involving greater technological efforts), the perceived demand is less elastic (potentially more appealing); hence, in response to stronger destination patent protection, source country firms respond with a reduced volume of exporting (i.e, lower quantity and higher prices) so as to maximize their profits.[25] This would be the kind of story consistent with our finding on the negative coefficient estimate of the interaction effect. The difference with Shin et al. (2016) is that we use a different, more comprehensive measure of technology levels (accommodating both input and output measures) and different samples of countries, particularly narrowing the destination countries to a top-twenty export market group for each source country. We believe that in the latter destination markets, source country firms with high technology levels are better able to exploit their market power given the occasion to do so under a stronger patent environment.

Next, using estimates from Table 5, we can compute the overall effects of destination patent rights ($PR_D$) on the exports of the source country (EXP), conditional on the source country's level of technological efforts ($TE_S$). From equation (2), we can calculate the following partial derivative:

$$\frac{\partial EXP}{\partial PR_D} = \hat{\alpha}_{15} + \hat{\alpha}_{16} \text{ x } TE_S$$

where the first term on the RHS is the individual contribution of destination patent protection on source country exports and the second term is the joint

[25]A plausible alternative explanation is that higher destination PRs and higher technological efforts in the source country motivate source country firms to switch from exporting to FDI abroad. This is left for future research to investigate.

effect of destination patent protection and source country technological level on source country exports, holding other determinants constant.

If we use the *random effects* estimates from column 8 of Table 3.5, we find $\frac{\partial EXP}{\partial PR_D} = 7.41 - 5.6 \, x \, TE_S$ for the high-income sample. Thus, the critical level of technology efforts is $TE_s^*$ = 1.32, where $TE_s^*$ solves for $\frac{\partial EXP}{\partial PR_D} = 0$.

In other words, for source countries whose technology level exceeds 1.32, the net effect of stronger destination patent rights is to reduce their exports (controlling for other factors). The market power effect of destination patent rights overwhelms the market expansion effect. But for source countries with lower levels of technology effects (i.e., $TE_S$< 1.32), destination patent rights have a net market expansion effect on their exports. Their technology levels are not high enough to permit a strong exercise of market power abroad.

In the high-income sample, the mean value of technology efforts (TE) is 1.76, and the median value is 1.8. Thus for most of these source countries, the net effect of destination patent rights is to reduce the volume of exporting. For about 35% of countries in our high income sample, namely economies with relatively lower levels of technology (for example Chile, Greece, Italy, Poland), destination patent rights help to spur their export. Note that this discussion applies to the high income sample. As Table 5 shows, for middle income countries, the joint effect of technology efforts and destination patent rights is insignificant.

### Table 3.5: Results of the export equation

| Dependent Variable: Exports | All countries | | | | High Income | | | | Middle Income | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FE | | RE | | FE | | RE | | FE | | RE | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $TE\_S_{t-1}$ | 11.00** | 10.02* | 15.44*** | 13.89*** | 20.69*** | 18.21** | 27.80*** | 24.35*** | 14.12 | 14.5 | 15.546 | 15.82 |
| | (5.71) | (5.99) | (5.49) | (5.71) | (8.17) | (8.63) | (7.89) | (8.27) | (18.13) | (19.33) | (18.07) | (18.59) |
| $PR\_D_{t-1}$ | 2.99** | 3.21** | 3.47*** | 3.71*** | 7.23*** | 6.40** | 7.90*** | 7.41*** | 4.45* | 4.51* | 5.05** | 5.02** |
| | (1.42) | (1.51) | (1.4) | (1.47) | (2.89) | (3.10) | (2.92) | (3.03) | (2.63) | (2.8) | (2.62) | (2.75) |
| $TE_{t-1}*PR\_D_{t-1}$ | -2.85** | -2.43* | -3.75*** | -3.20*** | -5.12*** | -4.36** | -6.57*** | -5.6*** | -3.71 | -3.8 | -4.07 | -4.17 |
| | (1.30) | (1.37) | (1.26) | (1.32) | (1.88) | (2.01) | (1.83) | (1.94) | (4.77) | (5.07) | (4.70) | (4.84) |
| $GDP\_D_{t-1}$ | | 0.25 | 0.05 | 0 .33 | | 0 .35 | | 0.44 | | -0.02 | | .01 |
| | | (0.43) | | (.43) | | (0 .62) | | (0.61) | | (0.78) | | (0.76) |
| $OPN\_D_{t-1}$ | | -3.31 | | -4.05 | | -2.49 | | -3.27 | | -.60 | | -.65 |
| | | (3.16) | | (3.02) | | (6.8) | | (6.23) | | (4.27) | | (4.06) |
| $EXR\_S_{t-1}$ | | -0.0004 | | -0.0004 | | 0.003 | | -0.002 | | -.0003 | | -.0003 |
| | | (0.0007) | | (.0006) | | (0.01) | | (0.004) | | .0007 | | (0.0007) |
| Constant | 3.63 | 3.99 | 0.61 | 1.29 | -12.51 | -9.41 | -17.14 | -14.25 | -2.64 | -2.08 | -5.24 | -4.74 |
| | (5.75) | (6.26) | (5.86) | 6.31 | (12.14) | (13.27) | (12.29) | (13.15) | (9.24) | (11.35) | (9.6) | (11.26) |
| Hausman test | 8.85** | 5.96 | | | 2.59 | 6.46 | | | 6.56 | 0.52 | | |
| | (0.03) | (0.42) | | | (0.46) | (0.37) | | | (0.36) | (0.99) | | |
| $R^2$ | 0.04 | 0.05 | 0.05 | 0.06 | 0.04 | 0.05 | 0.04 | 0.05 | 0.06 | 0.05 | 0.04 | 0.06 |
| Observations | 259 | 232 | 259 | 232 | 146 | 122 | 146 | 122 | 113 | 110 | 113 | 110 |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

### 3.5 Discussions

This study proposes an incremental perspective concerning the channel through which countries gain from strengthening PRs. It is hypothesized that PRs influences the technological efforts of a country that further stimulates its exports. We have empirically shown that a source country's PRs protection positively stimulates its technological efforts in both high-income and middle-income countries. The result is consistent with previous studies (Diwan and Rodrik, 1991; Gould and Gruben, 1996; Ginarte and Park, 1997; Park, 2008; Chen and Iyigun, 2011). Furthermore, the technological efforts of a source country positively influence the high technology exports of high-income countries. This empirical result is also confirmed in many studies (Cassiman et al., 2010; Shin, et al., 2016). But the empirical result indicates that technology efforts do not contribute to the high-tech exports of middle-income countries. A probable reason is that within developing countries, the technology efforts vary and some developing countries may be engaged in adaptive R&D for high-technology products that are in the second or third stage of product cycle development. In other words, their technology efforts fall short of some threshold level. In fact, some countries may even export such products if they are not protected by patents or are off-patents in the international markets. In this context, Park (2008) suggests that the adoption of stronger patent protection laws and the usage of patent rights vary across countries according to their levels of economic development.

The destination countries' PRs index is a positively significant determinant of source countries' incentive to export, which highlights that both high- and middle-income countries would export more to countries with a strong PRs protection, controlling for other factors. These results are also consistent with previous studies (Maskus and Penubarti, 1995; Smith, 2001; Park and Lippoldt, 2003; Ivus, 2010; Shin et al., 2016). However, an interesting finding is that the interaction coefficient of source countries TE and destination countries PRs is negatively related to exports for high-income countries whereas for middle-income countries, it is insignificant. For high-income countries, we explained that this is due to PRs having a net market power effect for technology intensive products, which moderates the market expansion effect of foreign patent rights. For middle-income countries, the technological efforts are still relatively low so that the technological intensity of their high-tech products does not condition the response of their exports to foreign patent regimes.

## 3.6 Robustness Check

In this study, we utilise another variable to check the sensitivity of results.

### 3.6.1 Sensitivity to Variable

In this study, we analyse the impact of source countries' PRs on technology efforts and its subsequent impact on their exports. To check the robustness of our results, it would be useful to incorporate labour productivity (output per worker) as a proxy variable for technology efforts; on the premise that it would be correlated with technical efficiency. Implicitly, we are assuming a production function in which technical efficiency is mainly labour augmenting. The change in the distribution of labour productivity is explained by the change in technology (Bernard and Jones, 1996). Table 3.6 presents the impact of a source country's PRs on labour productivity. The empirical result indicates that the patent rights of source countries positively influence the labour productivity of high-income countries. Technological infrastructure positively stimulates labour productivity as well of both high-income and middle income countries. Further, the result of the impact of labour productivity on exports is presented in Table 3.7. Interestingly, the result shows that this variable positively influences the exports of high income countries, and the patent rights of destination countries stimulate the exports of both high income and middle-income countries. Thus, our main results are robust to having labour productivity as a proxy variable for technological efforts.

**Table 3.6: Impact of PRs on labour productivity (LP) (as a robustness check)**

| Dependent variable: LogLP | All countries | | High Income | | Middle Income | |
|---|---|---|---|---|---|---|
| | FE | RE | FE | RE | FE | RE |
| $IPR\_S_{t-1}$ | 0.06*** | 0.06*** | 0.12*** | 0.12*** | -0.005 | -0.007 |
| | (0.01) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| $TII\_S_{t-1}$ | 0.78*** | 1.24*** | 0.18*** | 0.32*** | 2.35*** | 2.46*** |
| | (0.14) | (0.13) | (0.11) | (0.1) | (0.33) | (0.31) |
| Size_S | -0.0009 | -0.01*** | -0.001 | -0.005** | -0.0004 | -0.003 |
| | (0.003) | (0.003) | (0.004) | (0.003) | (0.005) | (0.004) |
| $Edn\_S_{t-1}$ | -0.00004 | 0.0003 | -0.0001 | -0.0001 | -0.001* | -0.001 |
| | (0.0006) | (0.0007) | (0.0006) | (0.0006) | (0.001) | (0.001) |
| Capital_S | 0.002 | -0.001 | -0.004 | -0.006** | 0.007 | 0.007 |
| | (0.002) | (0.002) | (0.003) | (0.003) | (0.005) | (0.005) |
| $OPN\_S_{t-1}$ | 0.23*** | 0.04 | 0.34*** | 0.23*** | 0.06 | 0.06 |
| | (0.05) | (0.04) | (0.06) | (0.05) | (0.09) | (0.09) |
| Constant | 9.7 | 10.21*** | 10.4*** | 10.7 | 8.95 | 8.95 |
| | (0.27) | (0.27) | (0.32) | (0.31) | (0.41) | (0.41) |
| Hausman test | 47.68*** | | 21.8*** | | 20.41*** | |
| | (0.00) | | (0.00) | | (0.00) | |
| R2 | 0.57 | 0.52 | 0.74 | 0.57 | 0.65 | 0.65 |
| Observation | 229 | 229 | 136 | 136 | 93 | 93 |

Note: Numbers in parentheses are standard errors. *, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

**Table 3.7: Impact of labour productivity (LP) on exports (as a robustness check)**

| Dependent Variable: Exports | All countries | | High Income | | Middle Income | |
|---|---|---|---|---|---|---|
| | FE | RE | FE | RE | FE | RE |
| LP_S $_{t-1}$ | 0.0001 | 13.89*** | 18.21** | 24.35*** | 14.5 | 15.82 |
| | (0.0002) | (5.71) | ( 8.63) | (8.27) | (19.33) | ( 18.59) |
| IPR_d $_{t-1}$ | 3.46* | 3.71*** | 6.40** | 7.41*** | 4.51* | 5.02** |
| | ( 2.01) | (1.47) | (3.10) | ( 3.03) | ( 2.8) | ( 2.75) |
| LP*IPR_d $_{t-1}$ | -0.00004 | -3.20*** | -4.36** | -5.6*** | -3.8 | -4.17 |
| | (0.00004) | (1.32) | ( 2.01) | ( 1.94) | 5.07 | (4.84) |
| GDP_D $_{t-1}$ | 0.15 | 0 .33 | 0 .35 | 0.44 | -0.02 | .01 |
| | (0.47) | (.43) | (0 .62) | (0.61) | ( .78) | ( .76) |
| OPN_D $_{t-1}$ | -3.35 | -4.05 | -2.49 | -3.27 | -.60 | -.65 |
| | (3.38) | (3.02) | ( 6.8) | ( 6.23) | (4.27) | ( 4.06) |
| EXR_S $_{t-1}$ | -0.0004 | -0.0004 | 0.003 | -0.002 | -.0003 | -.0003 |
| | 0.0007 | (.0006) | ( 0.01) | (0.004) | .0007 | ( .0007) |
| Constant | 4.69 | 1.29 | -9.41 | -14.25 | -2.08 | -4.74 |
| | (8.69) | 6.31 | (13.27) | (13.15) | ( 11.35) | (11.26) |
| Hausman test | 4.25 | | 6.46 | | 0.52 | |
| | ( 0.37) | | (0.37) | | (0.99) | |
| R2 | 0.04 | 0.06 | 0.05 | 0.05 | 0.05 | 0.06 |
| Observations | 232 | 232 | 122 | 122 | 110 | 110 |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote significant at 10, 5 and 1 percent levels respectively.

We find that TEs contribute to the exports of high-income countries. The results are not as compelling for middle-income countries due to the limited variation in their technological efforts, as explained earlier. The influence of technology efforts to exports is quite robust. Thus, our results corroborate earlier results of studies (e.g., Cassiman et al., 2010; Shin, et al., 2016) and once again highlight the divergence in technology efforts among middle-income countries and concomitantly their inability to translate these same efforts into high technology exports. Though similar evidence emerges regarding the positive influence of PRs in promoting exports, the results are not as robust when labour productivity is used instead of TE (see Table 3.8). This shows that while labor productivity is a reasonable indicator of output efficiency, it is not an ideal measure of the technological intensity of exportable products as our input and output measure of technological efforts.

**Table 3.8: Synthesis of the empirical results**

| **Dependent variable: Technology efforts (TE)**[26] | All countries | HI | MI |
|---|---|---|---|
| IPRs_S | +ve and significant | +ve and significant | +ve and significant |
| Robustness check (variable) | Holds | Holds | Does not hold |
| TII_S | +ve and significant | +ve and significant | +ve and significant |
| Robustness check (variable) | Holds | Holds | Holds |
| **Dependent variable: Exports**[27] | | | |
| TE_S | +ve and significant | +ve and significant | Not significant |
| Robustness check (variable) | Holds | Holds | Holds |
| IPR_D | +ve and significant | +ve and significant | +ve and significant |
| Robustness check (variable) | Holds | Holds | Holds |
| IPR_D*TE | -ve and significant | -ve and significant | Not significant |
| Robustness check (variable) | Holds | Holds | Holds |

## 3.7 Conclusion

This study investigates the impact of a source country's patent rights protection on its technological efforts and further studies the influence of technological efforts on exports using a panel data set of 67 countries from 1996 to 2014. This study constructs a technology efforts index by using principal component analysis (PCA) including both input and output indicators of innovation to analyse the technology efforts made by a country that contributes toward its export capacity across countries. To date, previous work has not constructed such a comprehensive index of technology effort, nor measured the influence that it has in facilitating the effects of patent laws on exporting.

We find strong evidence that patent protection stimulates domestic technological efforts and innovative activities in the source country. This is

[26] These results are based on fixed effects estimates.
[27] These results are based on random effects estimates.

after controlling for the technological infrastructure of countries, which also plays a significant role in enhancing the innovative activities of both high-income and middle-income countries. We find that technology efforts, as we have defined and constructed, increase the likelihood that high income countries become motivated to export high technology products. However, for middle-income countries, technology efforts do not contribute to their high technology exports. Thus, there appears to be some implied minimum economic development that needs to be reached for technology efforts to be a determining factor. We also examined the interaction between source countries' technology efforts and the destination countries' patent rights environment. The interaction effect has a negative influence on exports in high-income countries, suggesting that stronger destination patent rights enable source country firms to better exploit market power if they possess greater levels of technology.

We have approached the problem from the source country perspective in order to introduce variations in terms of host country factors. Further, as these economies have implemented patent policy changes to comply with TRIPs, such a study provides the empirical evidence about the impact of the agreement. As explained, there are variations in the technology efforts of middle-income countries that are captured through the index. However, the aggregate behavior, as reflected by the index needs to be further analysed, which remains for future work. Another avenue for future work is to integrate source country exports with source country outward foreign direct investment (FDI) activities. Under theories of internalization, it is well-known that firms choose among different modes of entry into foreign markets, with exporting and FDI being the key modes.

# Chapter 4

# Impact of Technological Efforts on the Extensive and the Intensive Margins of Trade

## 4.1 Introduction

Lessons from trade liberalisation show that export orientation rather than infant industry protection should be the strategy for economic development (Krueger, 1998; Lin and Chang, 2009). Also, studies suggest that changes in patent rights (PRs) have incentivised innovation in the developing countries after the passage of the agreement on trade-related intellectual property rights (TRIPs) under WTO. Such changes are influencing developing countries' innovation activities (research and development (R&D) and patenting), knowledge generation and diffusion, private investment flows along with their ability to purchase technology from international market (Braga1995; Maskus and Fink, 2005).

Technology is an important component of the international competitiveness of countries.[28] Developing countries, motivated to fill the gap and become internationally competitive, make extensive technological efforts (TEs) which are expected to contribute to their export performance. TEs capture the inputs and outputs associated with innovation activities. To capture the innovation by countries, existing studies use either input based measures like R&D expenditure or output based proxies like patents. As mentioned in the earlier essay (Chapter 3), Lall (2003) constructs an index of technology effort, based on national technological activity derived from two variables, such as R&D financed by productive enterprises and the number of patents taken out internationally whereas Shin et al. (2016) measure a country's level of technology by its patents. In consonance with Lall (2003),

[28] Scholars like Posner (1961), Vernon (1966), and Krugman (1979), etc., have emphasised the role of the technology gap, particularly in determining the trade pattern across countries.

we also construct a technological efforts (TEs) index as patents do not represent the complete innovation value chain. Considering that within the developing countries, different variants of 'effort' may exist, we extend Lall (2003) index by including different input and output indicators of innovation. The TEs index ranges from 0 to 5.5 where higher values indicate intensive innovation activity. High- and middle-income countries' average values of the TEs index are1.9 and 0.41 and maximum value of TEs index are 5.5 and 2.14, respectively.

Extensive literature also suggests that the evidence on the role of technology in developing country's export is inconclusive (Willmore, 1992; Siddharthan, 1994; Chadha, 2009; Shin et al., 2016). For instance, as we discussed in the earlier essay that some developing countries are engaged in adaptive R&D for high-technology products, which are in the second or third stage of product cycle development. Some other countries even may export such products if they are not protected or are off-patent in the international markets.[29] In the meantime, there are countries which may have evolved up the technology ladder in a few sectors to produce and export patented products that may be in the first stage of their product cycle development.[30]

Recent studies in international trade explore the extensive and intensive margins of trade. The extensive margin is defined as a change in the number of trading partners or number of products traded. It captures the increase in variety of exports and shows the changes in tastes of the importer, as consumers abroad seek to try new goods. The intensive margin is defined as the change in volume of trade among two countries. It captures how exports are spread across varieties. As we discussed earlier, there are variations among the developing countries in terms of technological efforts and its influence on export growth. The performance of trade margins in

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[29]India's exports of generic drugs are an example of such exported products.
[30]Patenting and exporting of Chinese solar panels is a case in point.

developing countries are also different among product groups (see Veeramani et al., 2018). Hence, we are interested to understand the patterns of bilateral trade and the product dimension cross countries at disaggregated level.

Previous studies in international trade examine the impact of several policies, namely, trade liberalisation, membership in multilateral organisation, hosting mega-events (namely, the Olympics and the World Cup), and PRs on bilateral trade flows (Rose, 2004; Rose and Spiegel, 2011; Dutt et al., 2013; Ndubuisi and Foster, 2018). Ndubuisi and Foster (2018) examine the impact of source countries' PRs on bilateral exports along the extensive and intensive margins. They suggest that strong PRs of source countries stimulate exports along with extensive margins. However, these studies do not consider the impact of source countries' TEs on trade margins. As in the second essay (Chapter 3), we have shown that PRs influence TEs of a country, however, if such TEs determine the trade margins remain unexplored. Therefore, this essay, utilising disaggregated products-level export data, explores the impact of TEs on bilateral exports by decomposing total exports into two margins of trade — extensive and intensive margins.

The traditional empirical model usually analyses the bilateral gravity works. Generally, scholars have widely employed the log-linear gravity model of trade to analyse trade flows. But recent empirical trade literature points out that the traditional log-linear gravity model leads to inconsistent estimates in the presence of heteroskedastic residuals. Liu (2009), Silva and Tenreyro (2006) and Felbermayr and Kohler (2006 and 2010) have observed that under heteroskedasticity, the parameters of log-linearised models estimated by ordinary least squares (OLS) lead to biased estimates of the true elasticities. Many other studies, such as Flowerdew and Aitkin (1982), and Silva and Tenreyro (2006) have proposed the Poisson regression as an alternative solution. Therefore, in this study, we have implemented the

Poisson Pseudo-Maximum Likelihood (PPML) estimation proposed by Silva and Tenreyro (2006) as an appropriate methodology to estimate the impact of technological efforts on bilateral exports along with the extensive and intensive margin of trade.[31]

In this essay, we are interested in exports data of PRs sensitive or knowledge-intensive goods at 6-digit product level— and further use it to construct the trade margins. We have observed that countries' TEs boost exports along extensive and intensive margins. To the extent, the findings of our study support both the trade margins hold. Our paper contributes to the existing literature by examining the role of TEs on the bilateral exports along with margins of trade— extensive and intensive margins. This study constructs a technology efforts (TE) index by employing principal component analysis (PCA), including both input and output indicators of innovation. In a gravity model setting, this study utilises the time-varying importer and exporter fixed effect to minimise the problem of omitted variable bias. We have used the PPML estimation model for the zero trade flows to account for heteroskedasticity, sample selection bias, and we implemented the country dyadic fixed-effects, the Poisson fixed-effects model to account for endogeneity issue. By using 6-digit product-level export data, we find a sharp increase in exports along with extensive and intensive margins through countries technological efforts.

The rest of the essay is organised as follows: next section sets the background by reviewing the existing evidence on TEs, PRs, exports, and trade margins by describing their inter-relationship. Section 4.3 presents methodology, and estimation challenges. Section 4.4 provides details on the variables and data sources. The empirical results are presented in Section 4.5. Section 4.6 presents the synthesis of the empirical results. Section 4.7

[31] There is a considerable trade-off between the quality of exports data and their variances in disaggregated trade flows. Usually, the first order condition of the Poisson model gives the same weight to all observations, hence, in presence of heteroskedasticity, the Poisson model performs extraordinarily better than other models (Silva and Tenreyro 2006).

provides robustness checks of the results. Section 4.8 summarises and concludes the essay.

## 4.2 Literature Review

Post globalization, there has been a significant change in the world trade as the share of emerging economies increased in the manufacturing exports (Tewari and Veeramani, 2016). It is very important for every economy to boost their industrial output for which innovative technologies and products are required. By exporting, firms exploit idle operating capacity, develop production efficiency, and improve technological quality and service standard that raises their profits and returns to investment. Furthermore, such activities generate funds for future investment and growth (Guan and Ma, 2003). Studies argue that export performance is enhanced when countries, specifically, developing economies, are able to move beyond trade in primary and low technology goods to high-technology products (Lall, 2000; Srholec, 2007).

With the aim to understand different trade patterns, existing literature analyses the importance of firms' extensive and intensive margins of international trade. Notably, Melitz (2003), Helpman et al. (2008) and Chaney (2008) explicitly develop trade models that reflect the decision to export, particularly the extensive margin of trade. Exports can differ across trading partners along with extensive and intensive margins of trade. Even though Melitz (2003) emphasises on the extensive margin of trade, a question arises that how these trade margins are important across developing countries along with their technological capacity. Owing to the extensive margin, there is a variation in trade across trading partners, while a change in the value of trade across one-year interval is due to the intensive margins (Bernard et al., 2009). Various studies have pointed out the importance of the intensive margin of trade for long-run export growth. Krugman (1980) envisages that all export variations happen only on intensive margin of trade because all firms are interested to exports to destination countries. Increases in the extensive margin or export diversification reduce the risk of crises in the balance of payments as well as large fluctuations in domestic output (Agosin, 2007; Lederman and Maloney, 2003). As the new exporting basket can improve the use and allocative efficiency of the economy, Feenstra and Kee (2008) suggest that, increases in sectoral export variety boost country productivity. Interestingly, Fernandes et al. (2016) suggest that larger economies and more developed economies have immense number of exporters. As countries develop and their exports grow, the expansion happens through both the extensive and the intensive margins, and more resources flow to the largest firms. They have found out a relatively larger role for the extensive margin in explaining why larger countries export larger volumes consistent with the standard model of trade with heterogeneous firms.

Besedes and Prusa (2010) argue that for long-run export growth, the survival of trading relationships is important. It implies that a critical part of improved export growth for developing countries may be focusing on existing relationships. Veeramani et al. (2018) perform a comparative analysis of trade margins in emerging countries, namely India and China. They suggest that India’s exports are lagging behind China’s exports along with the intensive margin. Within all product sectors, they find that there is a huge gap among India-China export performance in quantity margin. Mostly, India’s export growth is in favour of human capital- and technology-intensive products, however, India does not concentrate on unskilled labour-intensive products and network products groups. They also argue that China’s exporting is biased towards high-income partner countries by specializing in labor-intensive products.

Many empirical studies examine the impact of several trade policies on the margins of trade. With a large panel data set of 175 countries, Rose (2004) suggests that joining GATT/WTO has encouraged trade. Moreover, Rose and Spiegel (2011) argue that hosting mega-events also enhance exports.

By using 6-digit bilateral trade data, Dutt et al. (2013) investigate the effect of WTO/GATT membership on the extensive and intensive of trade. This study has found mixed results, such as WTO membership has a positive impact on the extensive product margin of trade, however, it is negatively related to the intensive margin. Foster (2014) suggests that destination countries' PRs affect export positively (negative) along with extensive (intensive) margin. A study by Ndubuisi and Foster (2018), examines the impact of source countries' PRs on bilateral exports along with extensive and intensive margins. They find that strong PRs of the source country matters more to the exporters than the level of destination country's PRs. They suggest that strong PRs of source countries stimulate exports along with extensive margins. However, these studies do not take into consideration the TEs of the country. We argue in this paper that TEs determine the bilateral exports along with margins of trade.

From the above discussions, we present our hypothesis regarding the effect of TEs on exporting across countries:

**H1a**: *Source countries' TEs influence bilateral export positively.*

**H1b:** *Source countries' TEs influence trade margins positively.*

The impact of destination countries' stronger PRs protection varies with existing TEs and the ability to innovate of source countries. TEs are positively correlated with export performances, through the proper enforcement of PRs. PRs influence countries' investment in innovative technologies that strengthen the competitiveness of industries (Cooper, 1991; Gold, 1982). A set of literature suggests that strong PRs in developing countries increase the value of developed countries' exports in patent-sensitive industries or high technology industries and enhance the product variety (Ivus, 2010 and 2015). Yang and Maskus (2009) suggest that strong patent protection enhances export platforms. Briggs and Park (2014) find that PRs play an important role in strengthening a local firm's position in technology trade. Kabir and Salim (2016) find that destination countries' strong PRs protection has a positive impact on China's export flows. Shin et al. (2016) argue that if a source country has a high level of technology, then stronger foreign PRs protection spurs exporters to enhance the volume of exports. Studies conclude that there is an ambiguous relationship between strong PRs and trade flows, because of their two opposing effects, such as market-expansion effects and market-power effects. Strong PRs, through "market-expansion effect," allows firms to increase the market in the host country by reducing imitation. On the other hand, strong PRs may also result in a "market-power effect" that induces the firm to restrain their production. The market-power effect reduces the elasticity of demand for a firm that ordinarily induces firms to export less of its patentable product (Taylor, 1993; Muskas and Penubarti, 1995; Smith, 2001).

Following Shin et al. (2016), we capture the combined effects of the TEs of a source country and PRs of destination countries on the source countries' bilateral exports. They have studied the interaction impact of a destination country's PRs' protection and a source country's level of technology on exports. They have found that foreign PRs influence the marginal contribution of technology to export performance, and the innovative capacity of the source country influences the relationship between PRs and trade. An introduction of variation in the innovation activity of developing countries will further help us in analysing the impact of destination countries' PRs on exports from such countries that Shin et al. (2016) could not capture. Thus, it is pertinent to study the interaction impact between TEs of a source country and the PRs of destination countries on bilateral exports along with trade margins. From the above discussions, we present following hypotheses:

> **H2a:** *Destination countries' PRs influence bilateral export along with margins of trade positively.*

**H2b:** *Possibly negative interaction effect between source countries' TEs and destination countries' PRs on bilateral exports along with margins of trade.*

### 4.3 Methodology

In a gravity model (GM) setting, this study examines the impact of technological efforts on exports along with margins of trade, to understand the bilateral export flows of 56 countries during 1996-2014. By analysing the relationship between economic size and distance (proxy for trade cost) among two countries (importer and exporter), such model is an important tool in the analysis of trade flows over many years. In this study, we estimate the model comprising importers' and exporters' gross domestic product (GDP) and series of trade costs. We develop the model with the key variables, namely, exporter TEs, importers PRs, and their interactions. Hence, our starting point for the analysis is the following equation:

$$\mathrm{EXP}_{ijt} = \mathrm{C}_1 + \alpha_{11}\mathrm{TE}_{it} + \alpha_{12}\mathrm{PR}_{jt} + \alpha_{13}\mathrm{TE}_{it} * \mathrm{PR}_{jt} + \alpha_{14}\mathrm{GDP}_{it} + \alpha_{15}\mathrm{GDP}_{jt} + \pi_i + \pi_j + \mu_t + \epsilon_{ijt} \quad (1)$$

Where $\mathrm{EXP}_{ijt}$represents the bilateral exports from country i to country j in period t. TE denotes the technology effort index, PR is the index of patent rights. GDP, the gross domestic product per capita growth (% annual). $\pi_i$ and $\pi_j$ capture the cultural and geographical proximities such as bilateral distance, official common language, share a common border, and colonial relationship across exporting and importing countries. The detailed reasons for introducing these variables are given later along with the construction of the variables.

#### 4.3.1 Estimation Challenges and Solutions

In estimating Equation (1), there is a need to address major challenges in order to obtain consistent estimates with the gravity model. We discuss and review all possible challenges and their solutions, which have been proposed in the literature, namely, multilateral resistance (MR), zero trade flows, heteroskedasticity of exports data, endogeneity issues and bilateral trade costs.

The MR is a noticeable challenge while estimating the Equation (1). It refers to the barriers that each of exporters (i) and importers (j) countries face in their trade with all their trading partners, such as domestic or internal trade.[32] The bilateral trade resistance denotes the size of the barriers to trade between countries i and j, whereas MR focuses on the third-party effects that need to be taken into account properly in an appropriate evaluation of the effect on trade flows (Anderson and van Wincoop, 2003; Baldwin and Taglioni , 2006; Adam and Cobham, 2007). Various solutions have been proposed to deal with such a challenge in the literature. In the beginning, iterative custom programming has been used to account for the multilateral resistances in a static setting, as developed by Anderson and van Wincoop (2003) in their original paper. Further, Baier and Bergstrand (2009) suggest a reduced form version, where a linear approximation of the MR called "remoteness indexes."[33] Such reduced form methods are criticised by Head and Mayer (2014). They suggest that such an approach has a little likeness to [their] theoretical counterpart. Hummels (2001) acclaims the use of exporter and importer (directional) fixed effects in cross-section estimations, Olivero and Yotov (2012) further extend such cross-section recommendations and validate that exporter-time and importer-time fixed effects will account for the MR in a dynamic gravity estimation.[34] Against this backdrop, we proposed to use the exporter-time and importer-time fixed effects to deal with the MR.

[32]See Anderson and van Wincoop (2003) who develop the "new" version of the gravity model with the presence of multilateral trade resistance.
[33]That is constructed as weighted averages of bilateral distance, with GDP used as weights.
[34]This approach will also absorb the size variable's frameworks with panel data while accounting for the unobservable multilateral resistance terms, see Anderson et al. (2015), and Larch and Yotov (2016) for further discussions.

In a gravity model framework, zero trade flows are obvious. Starting from Tinbergen (1962), ordinary least squares (OLS) regression technique has been employed extensively to estimate several forms of gravity equation enduring today. The OLS approach does not take care of the information contained in the zero trade flows. When the value of trade is transformed into a logarithmic form, such observations are simply dropped from the estimation sample. In this study, we utilise 6-digit disaggregated exports data; hence the problem with the zeros becomes more distinct with more disaggregated data. In our case, zeros account for around 16% of the pair trade links (see Figure 1). In the presence of zeros, studies suggest the use of Tobit estimators as an econometric solution (Eaton and Tamura, 1995; Martin and Pham, 2008). Though, this technique is silent on the determination of the Tobit threshold, it roots the disassociation between theory and estimation. To curb such problems, a two-step selection process has been proposed theoretically by Helpman et al. (2008).[35] With this approach, some difficulties arise for panel data estimations when dynamic considerations are taken into account. And it is also very hard to get good restriction for the first stage probit estimation. Finally, we consider the PPML estimator for gravity estimations[36] which is postulated by Silva and Tenreyro (2006).

The PPML model provides consistent estimates under general conditions. Trade data often have heteroskedasticity issues that can also be dealt with by employing PPML method (Silva and Tenreyro, 2006). To control the heteroskedasticity problem, Anderson and van Wincoop (2003) suggest transforming the dependent variable into size-adjusted trade, but this method has been criticised on the ground of zero trade flow challenge. PPML technique is an alternative and a more comprehensive approach. It

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[35]This model is estimated in two stages, estimation of Probit model in the first stage that determine the probability to exports. OLS technique will use for positive sample of trade flows in the second stage estimation.

[36] For detailed discussion see Silva and Tenreyro (2006 and 2011) and Head and Mayer (2014).

effectively handles the zero trade flow challenge in gravity model framework. The PPML model is consistent even when the variance function is mis-specified. The common assumption of the PPML estimation model is that the conditional variance is proportional to the conditional mean. If such assumption holds, the PPML estimator is likely to be more efficient than other estimators when heteroskedasticity increases with the conditional mean (Silva and Tenreyro, 2006).

While estimating Equation (1),[37] to account for the endogeneity issue, studies use instrumental variable approach. For example, Ivus (2010) utilises the colonial dummies in her study. However, such an instrument is time-invariant; hence it is not appropriate to our analysis. Therefore, due to lack of reliable instruments, many studies suggest using country pair dummies that are a comprehensive set of dyadic-specific fixed effects, which control time-invariant characteristics as common to a country pair. In gravity model, it should be noted that the set of pair fixed effects or the first difference has been used in order to eliminate the unobservable association between endogenous covariate and error terms (Baier and Bergstrand, 2007; Rose and Spiegel, 2011). Bilateral trade costs are also crucial for a gravity model analysis. We use a robust gravity proxy for trade costs, namely, bilateral distance among trading partners i and j, presence of contiguous borders, common official language, and presence of colonial ties.

### 4.4 Data

In this study, we are interested in exports data at product level and further use it to construct the margins — extensive and intensive margins across 56 countries during 1996-2014. Export data are extracted at the Harmonised System (HS) 6-digit level of disaggregation from UN Comtrade. We use

[37] The sources of endogeneity are model misspecification, measurement error, and simultaneity. An endogeneity problem occurs when there is a reverse causality where the policy variable may be associated with the unobservable cross-sectional trade costs variables.

different concordance tables[38] to convert all the data to HS-0 classification, as the Harmonised System (HS) classification has changed over time. Following Delgado et al. (2013) classification, we take high PRs sensitive products that are classified in the Standard International Trade Classification (SITC), then we made concordance between SITC and HS.

To build the margins of exports, studies apply different methods to decompose total exports into extensive and intensive margins (Hummels and Klenow, 2005; Bernard et al., 2009; Helpman et al. 2008; Dutt et al., 2013). Hummels and Klenow (2005) define the extensive margins (a wider set of goods) as a weighted count of the product groups that a country exports relative to the product groups exported by the rest of the world, and the intensive margins as countries export larger quantities of each good. Dutt et al. (2013) compare the count method and the Hummels and Klenow (2005) method of extensive and intensive margins, they find that the correlation between the count and the Hummels and Klenow (2005) method is around 0.86 % of the extensive margins and is around 0.88% of the intensive margins. Hence, we apply the count method to construct the margins. In a log-linear form, the decomposition of total exports (EXP) can be expressed as follows:

$$\ln \mathrm{EXP}_{ij,t} = \ln(\mathrm{N}_{ij,t}) + \ln\left(\frac{\mathrm{EXP}_{ij,t}}{\mathrm{N}_{ij,t}}\right) \quad (2)$$

where $\mathrm{EXP}_{ij,t}$, the real total bilateral exports (sum of total exports for all products for a given year). Total exports between a country pair is decomposed into two different dependent variables, namely, the extensive margin of exports as a count of number of HS-0 products that exported from i to j in period t, i.e., $\mathrm{N}_{ij,t}$, and the intensive margins as a simple average value of exports per product, i.e., $\mathrm{EXP}_{ij,t}/\mathrm{N}_{ij,t}$. The extensive margins of trade can account for a large share of the variation in imports and exports across

[38] Available at https://wits.worldbank.org/product_concordance.html

countries. The well-known “gravity’’ relationship between trade flows and distance, for example, is driven almost exclusively by the extensive margin: while the number of firms and the number of traded products decline significantly with distance, the intensive margin of average import or export value per firm-product, if anything, increases.

To capture the technological capacity of countries, this study computes a technology efforts (TEs) index by principal component analysis.[39] Five variables are included to construct the index where three of them represent input indicators: R&D expenditure as percentage of GDP, researchers in R&D per billion population, number of patent application by non-residents. The remaining two variables, the number of the patent application by residents and the number of published scientific and technical journal articles, represent output indicators. The last three variables (publications, non-resident patents, and resident patents) are standardised by real GDP to adjust for the economic size of a country. All these variables are collected from the World Development Indicator (WDI) and the World Intellectual Property Organization (WIPO). The TEs index ranges from 0 to 5.5, where higher values indicate intensive innovation activity. This study uses Ginarte and Park (1997) and Park (2008) PRs index[40] that indicates the strength of PRs protection in each country. GDP is taken from the WDI. All the gravity model variables including, bilateral distance, common border, common official language, colonial dummy is taken from CEPII database.[41] We estimate both equations (1) and (2) for a full sample,[42] and then estimate them by subgroups built on countries’ economic development— high-

[39]Principal component analysis (PCA) is a statistical procedure which converts an original set of observations, possibly correlated variables, into a substantially smaller set of uncorrelated variables that represent most of the information in the original set of variables (Hotelling 1933). Moreover, PCA reduces the dimensionality of the variable set and decomposes the total variance.

[40] Park and Ginarte (1997) develop the PRs’ index that indicates the strength of PRs protection in each country. The index ranges in value from 0 to 5, higher values of the index reflect stronger levels of protection. Further, Park (2008) extends the index to more countries and longer time.

[41]Available at http://www.cepii.fr

[42] 56 countries are included in this study based on data availability.

income and middle-income countries, as based on the World Bank (2016) classification of economies.[43]

Before moving for the empirical analysis, Table 4.1 provides the summary statistics of the variables, including the dependent and explanatory variables across 56 countries during 1996-2014. The total number of observations is 58,520, as there are 32 high-income countries and 24 middle-income countries. Exports values are in 1000 USD. Countries' TEs and PRs ranges from 0 to 5.5 and from 1.07 to 4.87 respectively. Panel B shows the source countries' TEs across different exporters' income groups. As expected, all mean, and maximum level of TEs surge simultaneously when we move from middle-income to the high-income countries suggesting that middle-income countries have lower technological capacity relative to high-income countries. Therefore, a significant component of our analysis is the development (namely, level of economic development, level of technological development) stage-dependent impact of TEs on exports, this makes an argument to grasp the distribution of export flows and adoption of TEs across different development level. Figure 1 specifies the bilateral trade flow (both positive and zero trade flows) across income groups. Zero trade flow emerge more in middle-income countries (32%) as compare to high-income countries (10%), thereby highlighting that high-income countries are more likely diversified and have more positive trade with different countries as relative to middle-income countries.

[43]Middle-income economies are those whose gross national income (GNI) per capita is more than $1,026 but less than $12,475 and high-income economies are those whose GNI per capita is $12,476 or more (World Bank 2016).

**Figure 4.1: Bilateral trade flow and income groups**

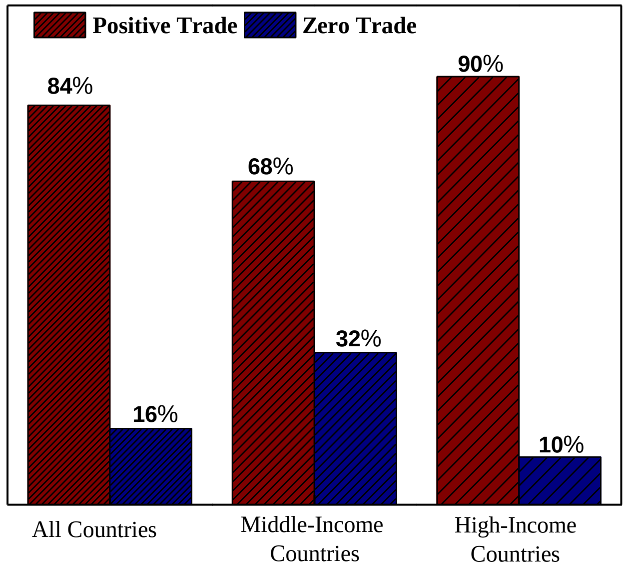


**Table 4. 1: Summary statistics**

| | No. of Observation | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| **Panel A = Full sample** | | | | | |
| Total Exports (EXP) | 58,520 | 532409.7 | 2574041 | 0 | 1.3E+08 |
| Extensive Margins (EXT_M) | 58,520 | 149.408 | 172.69 | 1 | 1254 |
| Intensive Margins (INT_M) | 58,520 | 1297.805 | 4708.142 | 0 | 214783 |
| Log EXP | 49,323 | 9.895 | 3.405 | 0 | 18.683 |
| Log EXT_M | 49,323 | 9.895 | 3.405 | 0 | 18.683 |
| Log INT_M | 49,323 | 5.550 | 2.009 | 0 | 12.277 |
| Technological Efforts ($TE_i$) | 58,520 | 1.398 | 1.234 | 0 | 5.509 |
| $PR_j$ | 58,520 | 3.724 | 0.850 | 1.075 | 4.875 |
| $TE_i$ * $PR_j$ | 58,520 | 5.268 | 4.953 | 0 | 26.857 |
| Log GDP | 58,520 | 26.037 | 1.710 | 21.753 | 30.464 |
| Log Distnace | 58,520 | 8.513 | 0.968 | 5.081 | 9.886 |
| Common Language | 58,520 | 0.084 | 0.278 | 0 | 1 |
| Common Boarder | 58,520 | 0.034 | 0.182 | 0 | 1 |
| Colony | 58,520 | 0.0 | 0.17 | 0 | 1 |
| **Panel B = TE across-income groups** | | | | | |
| Middle-Income | 25,080 | 0.41 | 0.45 | 0 | 1.999 |
| High-Income | 33,440 | 2.14 | 1.11 | 1.10E-09 | 5.509 |

Source: Authors' Calculation

## 4.5 Empirical Results

We present and discuss our empirical results for two categories, such as (a) full sample; (b) across income groups (level of economic development).

### 4.5.1 Technological Efforts and Exports – Full Sample

Table 4.2 presents the impact of TEs on exports utilising disaggregated exports data for the full sample. First, we discuss the empirical results for total exports in panel A. We utilise four econometric models with year fixed-effects. Model (1) begins from an OLS regression model with exporters and importers time fixed-effects for adjusted MR terms as described in the earlier section. Model (2) contains fixed effects (FEs) model with dyadic (pair) fixed-effects to account for pair-specific time invariant characteristics. Model (3) emerges when we utilise our preferred model, the PPML with only importer and exporter time fixed-effects. The final model, Model (4) comprises results when we implement the country's dyadic fixed-effects, the Poisson fixed-effects model. Model 4 is our chosen model specification, as we have discussed in detail in Section 4.3.1.

The empirical result shows that countries' TEs index is highly significant and positive across all models. It implies that strengthening countries' TEs increase bilateral exports flow. We find that destination countries' PRs are also positive and significant in Model (2) and Model (4) suggesting that importing countries' strong PRs protection positively stimulate exporting countries' bilateral exports. However, it is negative in Model (3). Thus, we obtain a mixed result for PRs signifying that importers' strong PRs either do not affect bilateral exports or it could be unsystematic owing to the limited variation of high-income countries' PRs protection. Further, following Shin et al. (2016), this study also controlled for an interaction effect, to capture the combined effects of the TEs of a source country and the PRs of destination countries on the bilateral exports of source countries. We have discussed in Section 2 that there is an ambiguous relationship between the PRs of destination countries and the trade flows of source countries. This is due to two opposing effects, such as the market expansion effects and market power effects. Our result indicates that the interaction coefficient is negatively related to exports in all models; that is, holding TE constant, a higher level of destination PR is associated with a lower volume of source exports. Therefore, where the exportable product was propelled by higher technological efforts, the market power effect of destination PRs dominates the market expansion effects on exports in the specific case.

Concerning to our control variables, we find the expected sign with statistically significant coefficients. Specifically, empirical result illustrates that both importer-and exporter-countries' GDP have a statistically significant with a positive sign, and we find a negative sign for bilateral distance. This is one of the most robust empirical finding in the international trade: bilateral trade between two countries is proportional to size, measured by GDP, and is inversely proportional to the geographic distance between them. The COMLAN and COLONY are positive and significant inferring that trade between bilateral pair increases if they stake an official language (COMLAN) and having colonial ties (COLONY) also increase bilateral trade. These results are consistence with empirical results in the existing literature. However, we find a significant and negative sign for CONTIG, suggesting a decrease of bilateral trade if they are adjacent to each other. A possible justification for this is that the border effect in trade refers to adjacent countries, but the border effect is heterogeneous across the region. Hence, such regions may not hold an economic coherent region.

In panel B, this study presents the empirical results of the decomposition of total exports (EXP), that is, extensive margin and intensive margin of exports. We follow each estimation technique as discussed earlier in panel A. For both the extensive and intensive export margins, across all estimated models, we find a robust statistically significant positive effect of exporters' TEs. This result specifies that countries' TEs boost exports along with extensive and intensive margins to the extent that the finding of our study supports both export margin holds. We recommend that countries' TEs advocate product diversification along with a long-run export growth in order to realise the growth and improve the productivity of exporters.

The importer countries' PRs are positive and significant in the preferred models for extensive export margin. However, this is insignificant for intensive export margin. This result suggests that destination countries' strong PRs works mostly for new trading relationships and product varieties. Romer (1990), argues that product variety is the source of growth. Our result of positive effect of importers' PRs on total exports that works mostly along extensive margins and it has also an important implication on growth and welfare.[44]

We find the same results across models for the interaction effects and for the control variables like the panel A. For the models (1) and (2), we use only positive trade flows, and for the models (3) and (4), this study utilises total bilateral trade flows including zero trade flows, as described in the earlier section.

[44] Romer (1994) emphasises the importance of product variety with an aim to achieve growth and welfare gains of trade.

**Table 4.2: Empirical results of TEs and exports: Full sample**

| VARIABLES | Panel A | | | | Panel B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Exports | | | | Extensive Margins | | | | Intensive Margins | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| $TE_i$ | 0.949*** | 0.390*** | 0.237*** | 0.086*** | 0.692*** | 0.388*** | 0.599*** | 0.151*** | 0.751*** | 0.006 | 0.135*** | 0.045*** |
| | (0.108) | (0.036) | (0.013) | (0.010) | (0.032) | (0.016) | (0.053) | (0.012) | (0.086) | (0.032) | (0.011) | (0.011) |
| $PR_j$ | -1.216 | 0.244*** | -0.352*** | 0.040*** | -1.216* | 0.273*** | -0.998*** | 0.088*** | 0.006 | -0.028* | -0.054 | 0.008 |
| | (1.387) | (0.018) | (0.072) | (0.006) | (0.662) | (0.008) | (0.114) | (0.007) | (1.100) | (0.016) | (0.068) | (0.006) |
| $TE_i*PR_j$ | -0.043*** | -0.086*** | -0.029*** | -0.025*** | -0.086*** | -0.104*** | -0.052*** | -0.045*** | 0.043*** | 0.017** | -0.012*** | -0.012*** |
| | (0.007) | (0.009) | (0.001) | (0.003) | (0.003) | (0.004) | (0.001) | (0.003) | (0.006) | (0.008) | (0.001) | (0.003) |
| $LGDP_i$ | 1.470*** | 0.923*** | 0.229*** | 0.220*** | 0.752*** | 0.411*** | 0.533*** | 0.231*** | 0.683*** | 0.507*** | 0.199*** | 0.210*** |
| | (0.053) | (0.023) | (0.014) | (0.006) | (0.018) | (0.010) | (0.062) | (0.007) | (0.042) | (0.021) | (0.011) | (0.006) |
| $LGDP_j$ | 1.599*** | 0.793*** | 0.310*** | 0.086*** | 1.022*** | 0.266*** | 0.557*** | 0.065*** | 0.574 | 0.525*** | 0.169*** | 0.099*** |
| | (0.593) | (0.023) | (0.033) | (0.005) | (0.283) | (0.010) | (0.047) | (0.006) | (0.470) | (0.021) | (0.031) | (0.006) |
| LDistance | -1.525*** | | -0.162*** | | -0.750*** | | -0.188*** | | -0.780*** | | -0.141*** | |
| | (0.011) | | (0.002) | | (0.005) | | (0.002) | | (0.008) | | (0.002) | |
| COMLAN | 0.672*** | | 0.095*** | | 0.390*** | | 0.122*** | | 0.289*** | | 0.074*** | |
| | (0.027) | | (0.004) | | (0.013) | | (0.005) | | (0.021) | | (0.004) | |
| CONTIG | -0.300*** | | -0.099*** | | -0.331*** | | -0.152*** | | 0.026 | | -0.056*** | |
| | (0.036) | | (0.005) | | (0.017) | | (0.007) | | (0.029) | | (0.005) | |
| COLONY | 0.691*** | | 0.071*** | | 0.469*** | | 0.108*** | | 0.220*** | | 0.039*** | |
| | (0.037) | | (0.005) | | (0.018) | | (0.007) | | (0.029) | | (0.005) | |
| Constant | -53.183*** | -37.524*** | -9.251*** | -6.419*** | -30.757*** | -15.254*** | -22.243*** | -7.038*** | -22.447*** | -22.075*** | -6.753*** | -7.037*** |
| | (9.960) | (0.801) | (0.710) | (0.221) | (4.734) | (0.355) | (1.942) | (0.246) | (7.893) | (0.718) | (0.635) | (0.230) |
| Observations | 49,195 | 49,195 | 58,520 | 58,520 | 49,323 | 49,323 | 53,222 | 56,677 | 49,195 | 49,195 | 58,520 | 58,520 |
| R-squared | 0.857 | 0.871 | 0.886 | 0.819 | 0.853 | 0.868 | 0.804 | 0.807 | 0.759 | 0.768 | 0.850 | 0.782 |
| Year FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Exporters FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Importers FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Pair FE | | yes | | yes | | yes | | yes | | yes | | yes |

Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

### 4.5.2 TEs and Exports: Level of Economic Development

We classify countries into two income groups, namely, middle-income (developing) countries and high-income (developed) countries based on the World Bank classification, as a proxy for the level of economic development. We employ four econometric models, as discussed earlier in sub-section (4.5.1). First, we discuss the results for developing countries' total exports in panel A (see Table 4.3).[45] The coefficient TE is positive and statistically significant, and robust to both exporter and importer fixed-effects, and country pair-fixed effects suggesting that developing countries' TEs significantly contribute to their bilateral exports. Hence, it indicates the significant importance of developing countries' TEs, and they involve in innovating at the frontier since countries are gaining significant weight in term of their bilateral exports of technology-sensitive products. Importer countries' PRs are also positive and highly significant, which indicate that strengthening destination countries' PRs enhance bilateral exports of the developing countries. The empirical result which shows that the interaction effect is negative and statistically significant, suggests the dominance of market power, as discussed earlier.

Panel B depicts the empirical results of the decomposition of total exports into extensive and intensive export margins. For the extensive export margins, the results indicate that a unit increase in the TEs index boosts exports along with the extensive export margin by 30-32%.[46] However, for intensive export margin, it accounts only for 10-11%. Hence, this result depicts that the adoption of technological capacity augments more varieties of products between country pairs for the developing countries. Interestingly, we find that destination countries' PRs are highly significant with positive signs across all model specifications, notwithstanding, they

[45] This study includes 24 middle-income countries as the exporters, and all 56 countries are the importer countries.
[46] The range is based on the coefficients of Model 3 and 4.

are insignificant for intensive margin in most models. It argues that the destination countries' strong PRs motivate developing countries' diversification of product, but it does not explain for its exports volume. This also suggests those destination countries' strong PR matters for exporters' product varieties. The interaction coefficient is negative and significant, showing that the dominance of market power effects on developing countries' bilateral exports along with trade margins in the preferred models.

Table 4.4 shows the developed countries' empirical results.[47] We find that TE coefficient is positive and statistically significant in the preferred model, which indicates that developed countries' TEs significantly contribute to their bilateral exports. We find a mixed result for destination countries' PRs for high-income countries' total exports, the possible reasons are discussed in the earlier section. The interaction coefficient is negative and significant, it shows that the existence of market power effects in high-income countries, as discussed earlier.

Panel B shows the results of trade margins. The empirical result shows that TEs stimulate exports along with extensive export margin, however, for the intensive margin of exports, it is insignificant across the chosen models. We also find a mixed result for destination countries' PRs for developed countries' bilateral exports along with extensive export margin. As we discussed earlier, importers' strong PRs either do not affect bilateral exports, or it could be unsystematic owing to the limited variation of high-income countries' PRs. For intensive export margin, the PRs coefficient is negative and significant, highlighting the fact that importers PRs do not contribute to high countries' exports volume. We find that an interaction coefficient is negatively related to extensive exports margins, but positively related to intensive export margin. It reveals that the market expansion

[47]This study includes 32 high-income countries as the exporters, and all (56) countries are the importer countries.

effect of destination PRs dominated the market power effects on exports in this specific case, where the exportable product was not driven by higher technological efforts and vice-versa. We also find the same signs and significance level for the control variables across the models along with trade margins in Tables 4.2 as discussed in the earlier subsection.

## Table 4.3: Empirical results of TEs and exports: Middle-income countries

| | Panel A | | | | Panel B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Exports | | | | Extensive Margins | | | | Intensive Margins | | | |
| VARIABLES | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| $TE_i$ | 0.117 | 0.306* | 0.191*** | 0.160*** | 0.125 | 0.496*** | 0.329*** | 0.303*** | -0.038 | -0.189 | 0.119*** | 0.096* |
| | (0.200) | (0.186) | (0.033) | (0.048) | (0.082) | (0.077) | (0.043) | (0.055) | (0.166) | (0.165) | (0.033) | (0.050) |
| $PR_j$ | 0.282 | 0.322*** | 0.023 | 0.033*** | 0.202* | 0.265*** | 0.108* | 0.077*** | 0.081 | 0.058* | 0.024 | 0.010 |
| | (0.291) | (0.038) | (0.040) | (0.012) | (0.120) | (0.016) | (0.060) | (0.014) | (0.241) | (0.034) | (0.038) | (0.012) |
| $TE_i*PR_j$ | -0.105*** | 0.009 | -0.072*** | -0.029** | -0.097*** | -0.154*** | -0.122*** | -0.086*** | -0.007 | 0.164*** | -0.044*** | -0.000 |
| | (0.038) | (0.046) | (0.007) | (0.012) | (0.016) | (0.019) | (0.009) | (0.014) | (0.031) | (0.040) | (0.007) | (0.012) |
| $LGDP_i$ | 2.291*** | 0.625*** | 0.234*** | 0.047*** | 0.974*** | 0.136*** | 0.248*** | 0.016 | 1.256*** | 0.480*** | 0.220*** | 0.065*** |
| | (0.067) | (0.052) | (0.011) | (0.014) | (0.030) | (0.022) | (0.011) | (0.016) | (0.055) | (0.046) | (0.013) | (0.014) |
| $LGDP_j$ | 1.172*** | 0.800*** | 0.182*** | 0.111*** | 0.704*** | 0.319*** | 0.178*** | 0.113*** | 0.469*** | 0.474*** | 0.163*** | 0.105*** |
| | (0.196) | (0.054) | (0.021) | (0.014) | (0.081) | (0.022) | (0.023) | (0.016) | (0.163) | (0.047) | (0.019) | (0.015) |
| Ldistance | -2.077*** | | -0.279*** | | -1.052*** | | -0.353*** | | -1.031*** | | -0.224*** | |
| | (0.023) | | (0.004) | | (0.009) | | (0.005) | | (0.019) | | (0.004) | |
| Comlang | 0.731*** | | 0.171*** | | 0.529*** | | 0.260*** | | 0.210*** | | 0.110*** | |
| | (0.056) | | (0.009) | | (0.023) | | (0.012) | | (0.046) | | (0.009) | |
| Contig | -0.155* | | -0.092*** | | -0.037 | | -0.126*** | | -0.121* | | -0.067*** | |
| | (0.083) | | (0.012) | | (0.034) | | (0.015) | | (0.069) | | (0.011) | |
| Colony | 0.855*** | | 0.090*** | | 0.587*** | | 0.137*** | | 0.263*** | | 0.047*** | |
| | (0.081) | | (0.011) | | (0.033) | | (0.014) | | (0.067) | | (0.011) | |
| Constant | -59.917*** | -30.869*** | -5.986*** | -3.116*** | -29.452*** | -9.936*** | -6.667*** | -3.417*** | -29.045*** | -20.572*** | -6.249*** | -3.896*** |
| | (5.091) | (1.785) | (0.604) | (0.488) | (2.115) | (0.737) | (0.769) | (0.552) | (4.219) | (1.579) | (0.572) | (0.502) |
| Observations | 16,986 | 16,986 | 25,080 | 25,080 | 17,114 | 17,114 | 20,418 | 23,351 | 16,986 | 16,986 | 25,080 | 25,080 |
| R-squared | 0.816 | 0.831 | 0.869 | 0.737 | 0.860 | 0.860 | 0.793 | 0.730 | 0.679 | 0.697 | 0.820 | 0.685 |
| Year FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Exporters FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Importers FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Pair FE | | yes | | yes | | yes | | yes | | yes | | yes |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

### Table 4.4: Empirical results of TEs and exports: High-income countries

| | Panel A | | | | Panel B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Exports | | | | Extensive Margins | | | | Intensive Margins | | | |
| VARIABLES | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| $TE_i$ | 0.189*** | 0.286*** | 0.088*** | 0.043*** | 0.455*** | 0.298*** | 0.207*** | 0.086*** | -0.266*** | -0.012 | -0.005 | 0.011 |
| | (0.054) | (0.032) | (0.008) | (0.009) | (0.028) | (0.015) | (0.018) | (0.010) | (0.043) | (0.029) | (0.010) | (0.011) |
| $PR_j$ | -1.311 | 0.160*** | -0.429*** | 0.019*** | -1.386** | 0.240*** | -1.159*** | 0.060*** | 0.076 | -0.079*** | -0.078 | -0.011* |
| | (1.109) | (0.019) | (0.078) | (0.006) | (0.570) | (0.009) | (0.113) | (0.007) | (0.883) | (0.017) | (0.072) | (0.006) |
| $TE_i*PR_j$ | 0.022*** | -0.065*** | -0.010*** | -0.010*** | -0.066*** | -0.074*** | -0.031*** | -0.021*** | 0.088*** | 0.009 | 0.006*** | -0.001 |
| | (0.008) | (0.008) | (0.001) | (0.002) | (0.004) | (0.004) | (0.002) | (0.003) | (0.006) | (0.007) | (0.002) | (0.003) |
| $LGDP_i$ | 1.352*** | 1.177*** | 0.137*** | 0.204*** | 0.685*** | 0.650*** | 0.218*** | 0.241*** | 0.666*** | 0.527*** | 0.119*** | 0.174*** |
| | (0.028) | (0.029) | (0.007) | (0.007) | (0.015) | (0.014) | (0.014) | (0.008) | (0.023) | (0.027) | (0.008) | (0.007) |
| $LGDP_j$ | 1.532*** | 0.802*** | 0.361*** | 0.081*** | 1.020*** | 0.250*** | 0.791*** | 0.055*** | 0.512 | 0.552*** | 0.151*** | 0.101*** |
| | (0.450) | (0.022) | (0.045) | (0.004) | (0.231) | (0.010) | (0.065) | (0.005) | (0.358) | (0.020) | (0.042) | (0.005) |
| Ldistance | -1.306*** | | -0.120*** | | -0.592*** | | -0.125*** | | -0.714*** | | -0.115*** | |
| | (0.011) | | (0.002) | | (0.006) | | (0.002) | | (0.009) | | (0.002) | |
| Comlang | 0.514*** | | 0.050*** | | 0.262*** | | 0.059*** | | 0.253*** | | 0.043*** | |
| | (0.027) | | (0.003) | | (0.014) | | (0.004) | | (0.021) | | (0.004) | |
| Contig | -0.179*** | | -0.059*** | | -0.288*** | | -0.097*** | | 0.109*** | | -0.027*** | |
| | (0.035) | | (0.004) | | (0.018) | | (0.006) | | (0.028) | | (0.004) | |
| Colony | 0.540*** | | 0.054*** | | 0.386*** | | 0.084*** | | 0.154*** | | 0.029*** | |
| | (0.036) | | (0.005) | | (0.019) | | (0.006) | | (0.029) | | (0.004) | |
| Constant | -48.776*** | -43.862*** | -8.081*** | -5.696*** | -29.393*** | -20.856*** | -19.333*** | -6.858*** | -19.380*** | -23.004*** | -4.118*** | -5.973*** |
| | (7.295) | (0.912) | (0.883) | (0.223) | (3.747) | (0.439) | (1.322) | (0.253) | (5.806) | (0.835) | (0.840) | (0.238) |
| Observations | 32,209 | 32,209 | 33,440 | 33,440 | 32,209 | 32,209 | 32,804 | 33,326 | 32,209 | 32,209 | 33,440 | 33,440 |
| R-squared | 0.889 | 0.906 | 0.876 | 0.850 | 0.863 | 0.879 | 0.804 | 0.834 | 0.813 | 0.829 | 0.839 | 0.826 |
| Year FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Exporters FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Importers FE | yes | | yes | | yes | | yes | | yes | | yes | |
| Pair FE | | yes | | yes | | yes | | yes | | yes | | yes |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

#### 4.5.2.1 TEs and Exports – Across Income Groups

This study further classifies the bilateral export flows across different income groups, such as bilateral export flows from middle-income (MI) to MI countries, from MI to high-income (HI) countries, from HI to MI, and from HI to HI countries, respectively in Table 4.5. We apply the Poisson fixed-effect model with year fixed-effects, i.e., the PPML model with country pair fixed-effects. Table 4.5 shows the results of bilateral export flows across different income group combinations. We find that TEs positively influence the bilateral export flows across different income combinations. TEs coefficient is highly significant for export flow from developing countries to developed countries. It depicts that the developing countries' high-technology products are more exported to developed countries. India's exports of generic drug and Chinese dominance in exporting of solar panels are a spot of such exporting. Moreover, we find that high-income countries' TEs are also positively influence bilateral export flows to developing countries, but not to the developed countries. Evidently, the share of high-income countries' exporting to middle-income countries, the case of China, is more compared to high-income countries. It also indicates that developed countries are already in the frontier of technology; hence they are not exporting the high-tech exports products as compared to developing countries. The companies for developed countries may be facing stiffer competition for their products, which may not be the case in other pairs. Destination countries' strong PRs positively stimulate the bilateral export flows from MI to MI, from MI to HI, and from HI to HI; however, it is negatively influencing the bilateral exports from HI to MI. A possible reason for this result is that developing countries' innovation is based on the weak threat of imitation, hence developing countries TEs is negatively related to high-income countries' exports. We find the interaction coefficient is negatively related to bilateral export flows across all combinations.

Panel B shows the impact of TEs on extensive and intensive export margins. The positive TEs encourage the quality of exports (product varieties) across all combinations except bilateral export flows from HI to HI. Export volume is positively influenced by countries' TEs across all income groups' combination except bilateral export flows from MI to MI. We find that enforcement of strong PRs has a positive impact on export margins, when we move the bilateral exports from MI to MI and from MI to HI, yet in contrary, when we move the bilateral exports from HI to MI and from HI to HI across the extensive and intensive export margins. The possible reason could be the less variability in the strength of PRs in developed countries. The interaction effects are also negative and significantly different across bilateral export flows and across export margins; the possible reasons are discussed in earlier sections.

**Table 4.5: Empirical results of TEs and exports: across-income groups**

| Variables | Panel A | | | | Panel B | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Exports | | | | Extensive Margins | | | | Intensive Margins | | | |
| | MI to MI | MI to HI | HI to MI | HI to HI | MI to MI | MI to HI | HI to MI | HI to HI | MI to MI | MI to HI | HI to MI | HI to HI |
| $TE_i$ | 0.116* | 0.467*** | 0.025*** | 0.013 | 0.248*** | 0.829*** | 0.033*** | -0.004 | 0.062 | 0.275** | 0.020** | 0.026* |
| | (0.059) | (0.109) | (0.007) | (0.012) | (0.069) | (0.124) | (0.007) | (0.012) | (0.062) | (0.112) | (0.008) | (0.013) |
| $PR_j$ | 0.035** | 0.100*** | -0.023*** | 0.004*** | 0.083*** | 0.175*** | -0.009*** | -0.006*** | 0.011 | 0.063** | -0.015*** | 0.001 |
| | (0.017) | (0.026) | (0.001) | (0.001) | (0.020) | (0.031) | (0.001) | (0.001) | (0.017) | (0.027) | (0.001) | (0.001) |
| $TE_i$*$PR_j$ | -0.019 | -0.098*** | -0.006*** | -0.002 | -0.088*** | -0.199*** | -0.011*** | 0.002 | 0.015 | -0.044* | -0.003 | -0.004 |
| | (0.017) | (0.025) | (0.002) | (0.003) | (0.020) | (0.028) | (0.002) | (0.003) | (0.018) | (0.025) | (0.002) | (0.003) |
| $LGDP_i$ | 0.024 | 0.066*** | 0.229*** | 0.192*** | -0.005 | 0.044** | 0.311*** | 0.208*** | 0.046** | 0.077*** | 0.164*** | 0.177*** |
| | (0.022) | (0.018) | (0.010] | (0.009) | (0.026) | (0.020) | (0.012) | (0.010) | (0.023) | (0.018) | (0.012) | (0.010) |
| $LGDP_j$ | 0.084*** | 0.125*** | 0.080*** | 0.077*** | 0.104*** | 0.120*** | 0.030*** | 0.066*** | 0.070*** | 0.122*** | 0.117*** | 0.085*** |
| | (0.023) | (0.026) | (0.007) | (0.008) | (0.026) | (0.029) | (0.008) | (0.009) | (0.024) | (0.027) | (0.008) | (0.009) |
| Constant | -1.235 | -4.240*** | -6.336*** | -5.201*** | -1.942** | -4.702*** | -8.151*** | -6.045*** | -1.990*** | -4.881*** | -6.141*** | -5.722*** |
| | (0.756) | (0.800) | (0.338) | (0.336) | (0.881) | (0.881) | (0.388) | (0.370) | (0.772) | (0.825) | (0.372) | (0.353) |
| Observations | 10,488 | 14,592 | 14,592 | 18,848 | 9,462 | 13,889 | 14,497 | 18,829 | 10,488 | 14,592 | 14,592 | 18,848 |
| R-squared | 0.763 | 0.718 | 0.873 | 0.817 | 0.759 | 0.709 | 0.869 | 0.785 | 0.695 | 0.676 | 0.817 | 0.818 |
| Year FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Pair FE | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |

Note: Numbers in parentheses are standard errors.
*, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

### 4.6 Synthesis of the Empirical Results

Based on the preferred model, Table 4.6 presents the synthesis of the empirical results. TEs augment the bilateral exports along with trade margins across countries. Countries technological efforts increase the likelihood that countries become motivated to export high technology products along with product varieties and volume of exports. Destination countries' PRs protection enhances bilateral exports along with extensive margins of exports. Our result indicates that interaction coefficient (between TEs and PRs) is negatively related to exports that is, holding TEs constant, a higher level of destination PRs is associated with a lower volume of source exports. Therefore, where the exportable product was propelled by higher technological efforts, the market power effect of destination PRs dominates the market expansion effects on exports.

In the case of developing countries, the results indicate that a unit increase in the TEs boosts exports along with extensive export margin by 30-32%. However, for intensive export margin, it accounts only for 10-11%. Hence, this result depicts that the adoption of technological capacity augments more varieties of products between country pairs for the developing countries. For high-income countries, we find that TEs encourage exports along with extensive export margin, however, for intensive margin of exports, it is insignificant across the chosen model. Interestingly, we find that importers' PRs positively influence bilateral exports along extensive margins when exporting from MI to HI countries; however, when from HI to MI, it is negatively related. This result shows that developed countries have a strong threat to imitation along with market expansion effects, but developing countries pose a weak threat to imitation as well as the existence of market power effects.

We find that TEs positively influence the bilateral export flows across different income combinations. TEs coefficient is highly significant for export flows from developing countries to developed countries. It depicts that the developing countries' TEs contribute to the high-technology products that are more exported to developed countries. We find that high-income countries' TEs are also positively influence bilateral export flows to developing countries, but not to the developed countries. As developed countries are already on the frontier of technology, they are not exporting the high-tech exports products as compared to developing countries. The companies for developed countries may be facing stiffer competition for their product which may not be the case in other pairs. Based on the results, we suggest that middle-income countries should support exporters in marketing of the products, brand creation through various schemes including participation in international trade fairs to increase the intensive margins. Policymakers of the middle-income countries may devise schemes to reduce the cost of exporters for patenting in different countries and ensure that market power enjoyed by the high-income countries' exporters is not abused.

**Table 4.6: Synthesis of the empirical results**

| **Full Sample** | **Total Exports** | **Extensive Margin** | **Intensive Margin** |
|---|---|---|---|
| $TE_i$ | +ve and significant | +ve and significant | +ve and significant |
| $PR_j$ | +ve and significant | +ve and significant | Not significant |
| PR*TE | -ve and significant | -ve and significant | -ve and significant |
| **Middle Income** | | | |
| $TE_i$ | +ve and significant | +ve and significant | +ve and significant |
| $PR_j$ | +ve and significant | +ve and significant | Not significant |
| PR*TE | -ve and significant | -ve and significant | Not significant |
| **High- Income** | | | |
| $TE_i$ | +ve and significant | +ve and significant | Not significant |
| $PR_j$ | +ve and significant | +ve and significant | -ve and significant |
| PR*TE | -ve and significant | -ve and significant | Not significant |
| **Across Income Group: MI-HI** | | | |
| $TE_i$ | +ve and significant | +ve and significant | +ve and significant |
| $PR_j$ | +ve and significant | +ve and significant | +ve and significant |
| PR*TE | -ve and significant | -ve and significant | -ve and significant |
| **Across Income Group: MI-MI** | | | |
| $TE_i$ | +ve and significant | +ve and significant | Not significant |

| | | | |
|---|---|---|---|
| $PR_j$ | +ve and significant | +ve and significant | Not significant |
| PR*TE | Not significant | -ve and significant | Not significant |
| **Across Income Group: HI-MI** | | | |
| $TE_i$ | +ve and significant | +ve and significant | +ve and significant |
| $PR_j$ | -ve and significant | -ve and significant | -ve and significant |
| PR*TE | -ve and significant | -ve and significant | Not significant |
| **Across Income Group: HI-HI** | | | |
| $TE_i$ | Not significant | Not significant | +ve and significant |
| $PR_j$ | +ve and significant | -ve and significant | Not significant |
| PR*TE | Not significant | Not significant | Not significant |

### 4.7 Sensitivity Analysis

In this study, we analyse the impacts of exporting countries' TEs on their bilateral exports and further on the decomposition of total exports — extensive and intensive export margins. To check the robustness of our results, we are interested to utilise the "distance to frontier" as a proxy variable for TEs. On the premise that it would be able to measure the technological gap of the exporters where low technology gaps lead high-tech exports and vice-versa.

In Table 4.7, by utilising the Poisson fixed-effect model, we find that countries' technological gap is negatively related to their bilateral exports along with extensive and intensive margins for the full sample. We also find that not only countries' product varieties, but long-run export growth is also negatively influenced by exporters' technological gap. We also have observed that importing countries' PRs is negatively related to their bilateral exports along with extensive across income groups. Interestingly, we have found an opposite sign of our main results for the interaction effects due to the distance to the frontier of countries' TEs. We also find that the interaction effect is positive and statistically significant across income groups along with export margins. Thus our main results are robust to having distance to frontier as a proxy variable for technological efforts.

**Table 4.7: Empirical results of technological gap and exports – full sample, HI and MI countries**

| VARIABLES | Full Sample | | | Middle-Income | | | High-Income | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total Exports | Extensive Margin | Intensive Margin | Total Exports | Extensive Margin | Intensive Margin | Total Exports | Extensive Margin | Intensive Margin |
| $Tech\_Frntr_i$ | -0.105*** | -0.123*** | -0.096*** | -0.160*** | -0.303*** | -0.096* | -0.043*** | -0.086*** | -0.011 |
| | (0.010) | (0.011) | (0.010) | (0.048) | (0.055) | (0.050) | (0.009) | (0.010) | (0.011) |
| $PR_j$ | -0.072*** | -0.076*** | -0.074*** | -0.025 | -0.095*** | 0.009 | -0.033*** | -0.058*** | -0.015 |
| | (0.008) | (0.009) | (0.008) | (0.020) | (0.023) | (0.022) | (0.009) | (0.009) | (0.010) |
| $TechFrntr_i*PR_j$ | 0.030*** | 0.039*** | 0.024*** | 0.029** | 0.086*** | 0.000 | 0.010*** | 0.021*** | 0.001 |
| | (0.002) | (0.003) | (0.002) | (0.012) | (0.014) | (0.012) | (0.002) | (0.003) | (0.003) |
| $LGDP_i$ | 0.221*** | 0.236*** | 0.207*** | 0.047*** | 0.016 | 0.065*** | 0.204*** | 0.241*** | 0.174*** |
| | (0.006) | (0.007) | (0.006) | (0.014) | (0.016) | (0.014) | (0.007) | (0.008) | (0.007) |
| $LGDP_j$ | 0.090*** | 0.074*** | 0.100*** | 0.111*** | 0.113*** | 0.105*** | 0.081*** | 0.055*** | 0.101*** |
| | (0.005) | (0.006) | (0.006) | (0.014) | (0.016) | (0.015) | ( [0.004) | (0.005) | (0.005) |
| Constant | -6.150*** | -6.880*** | -6.675*** | -2.795*** | -2.812*** | -3.704*** | -5.459*** | -6.383*** | -5.915*** |
| | (0.232) | (0.259) | (0.240) | (0.492) | (0.554) | (0.508) | (0.233) | (0.263) | (0.250) |
| Observations | 58,410 | 56,559 | 58,410 | 25,080 | 23,351 | 25,080 | 33,440 | 33,326 | 33,440 |
| R-squared | 0.819 | 0.807 | 0.782 | 0.737 | 0.730 | 0.685 | 0.850 | 0.834 | 0.826 |
| Year FE | Yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Pair FE | Yes | yes | yes | yes | yes | yes | yes | yes | yes |

Note: Numbers in parentheses are standard errors. *, ** and *** denote that coefficient is significant at 10, 5 and 1 percent levels respectively.

## 4.8 Conclusion

This study examines the impact of technological efforts on bilateral exports along with the margins of trade. In this study, we have implemented the Poisson Pseudo-Maximum Likelihood (PPML) estimation technique proposed by Silva and Tenreyro (2006) as an appropriate methodology to estimate the impact of technological efforts (TEs) on bilateral exports along with the extensive and intensive margin of trade across 56 countries during 1996-2014. To analyse the TEs, this study constructs a technology effort index using principal component analysis (PCA), using both input and output indicators of innovation, made by a country that contributes toward its bilateral export across countries. Furthermore, we have split our samples into two categories, such as (a) full sample; and (b) across income groups (based on the level of economic development).

We have found strong evidence that countries' TEs contribute to bilateral exports along with trade margins. Countries technological capacity increases the likelihood that countries become motivated to export high technology products along with product quality and export volumes. Importing countries PRs protection stimulates bilateral exports along with product variety; however, it does not contribute to exports volume. This result indicates that countries' patent rights enhance the quality of imports rather quantity/volume of exports. We have also examined the interaction between source countries' TEs and the destination countries' PRs environment. The fact that the interaction effect has a negative influence on exports in high-income countries suggests that stronger destination PRs enable source country firms to exploit market power better, if they possess a greater technological capacity.

Based on the level of economic development, this study reveals strong evidence that technological level augments bilateral exports only along with extensive margins. It implies that technological capacity plays a significant role in countries' product diversification and exports quality across income groups. Interestingly, we find that importers' PRs positively influence bilateral exports along with extensive margins when exporting from MI to HI countries; however, when from HI to MI, it is negatively related. This result shows that developed countries have strong threat to imitation along with market expansion effect, but developing countries pose weak threat to imitation as well as the existence of market power effects.

This study recommends that TEs advocate the product diversification along with a long-run export growth in order to improve exporters' productivity, improve allocative efficiency, and realise the economic development. Hence, these findings have implications for research on the effects of source countries' TEs, and destination countries' PRs on economic development. In future research, scholars can investigate the impact of higher technological efforts in the source country and higher destination PRs on foreign direct investment (FDI). Another avenue for future work is to integrate source country exports with source country outward foreign direct investment (FDI) activities. Under theories of internalization, it is well-known that firms choose among different modes of entry into foreign markets, with exporting and FDI being the key modes.

# Chapter 5

# Summary and Conclusion

This dissertation is a compilation of three essay with the broad concern to examine the impact of patent rights (PRs) protection on technological efforts of a country and their contribution to high-technology exports at both aggregated and disaggregated levels. Chapter 2 presents the first essay of this dissertation. We undertake an extensive review of literature on the relationships among PRs, innovation, and exports. Furthermore, we strengthened the review by a meta-regression analysis. Chapter 3 of this dissertation provides empirical evidence on the impact of source countries' PRs protections on technological efforts, and its contributions to exports. We provide an incremental perspective on an existing channel through which countries gain from PRs protection. Chapter 4 provides the impact of technological efforts on bilateral exports along with margins of trade—extensive and intensive margin of exports by using 6-digit product-level export data.

The present chapter is organised as follows: Section 5.1 summarizes the dissertation with the main findings of each essay. Section 5.2 draws policy implications. Section 5.3 elaborates upon contributions of the study. Section 5.4 delineates limitations of the dissertation and outlines directions for future research. 5.5 provides the concluding remarks.

## 5.1 Overall Summary

This study investigates the impact of a source country's patent rights protection on its technology efforts and further studies the influence of technology efforts on exports. This dissertation is a collection of three essays, each representing an individual chapter. In the first essay, we focus on the literature survey. The review is further strengthened by meta-regression analysis to understand the sensitivity of results of empirical studies to data, the period of study and most importantly to the level of economic development of sample countries. This dissertation examines the impact of patent rights protection on innovation across countries by conducting the meta-analysis based on 14 empirical studies undertaken during 1996-2019. Furthermore, we examine the impact of innovation on export performance by conducting the meta-regression analysis from 27 empirical studies during 1996-2019. For obtaining empirical studies, we undertake a comprehensive search of literature available on Google Scholar, JSTOR and other sources. We searched in the title, abstract of published works, working papers and conference papers for any reference to "intellectual property right" and "innovation"; "PRs and innovation"; "innovation" and "exports"; "innovation and exports" since 1996. Before performing a meta-regression analysis, we also test the publication trend adopted by authors or journals that relate to the direction of results or significance of coefficients.

The second essay of this dissertation studies how patent rights protection augments countries' technological efforts that further contribute to countries' high-technology exports. This study constructs a technology efforts index, using principal component analysis (PCA) including both input and output indicators of innovation to analyse the technological efforts made by a country that contributes toward its export capacity across countries. The technological efforts index ranges from 0 to 5.37 where higher values indicate intensive innovation activity. High- and middle-income countries' average values of the TEs index are 1.9 and 0.35 and maximum values of the TEs index are 5.37 and 1.99, respectively. We utilise a panel data set of 67 countries from 1996 to 2014. In the relationship between TEs and PRs equation, technology efforts (TEs) index is the dependent variable; key independent variables are PRs, it refers to the patent rights index that measures countries' strength of PRs protection, and technological infrastructure index (TII), which measures countries' technological infrastructure, using three different indicators of infrastructure: internet, telephone, and electricity. In relationship between TEs and exports, high technology exports as a percentage of manufactured exports, as the dependent variable; key independent variables are source countries' TEs, destination countries' PRs, and an interaction effect. We controlled for an interaction effect, following Shin et al. (2016), to capture the combined effects of the source counties' technological efforts and destination countries' patent rights (PRs) on the exports of source countries. To check the robustness of our results, we incorporate labour productivity (output per worker) as a proxy variable for technological efforts, and we find that our main results are robust to having labour productivity as a proxy variable for technological efforts.

In a gravity model setting, the third essay of this dissertation examines the impact of technological efforts on bilateral exports along with margins of trade. We utilise product-level exports data to analyse the relationship between technological efforts and export margins— extensive and intensive margins for 56 countries during 1996-2014. Export data are extracted at the Harmonised System (HS) 6-digit level of disaggregation from UN Comtrade. Following Delgado et al. (2013) classification, we take high PRs sensitive products that are classified in the Standard International Trade Classification (SITC), and then we made concordance between SITC and HS. To build the margins of exports, we apply the count method to construct the export margins. We implement the Poisson Pseudo-Maximum Likelihood (PPML) estimation technique as an appropriate methodology to estimate the impact of technological efforts on bilateral exports along with margin of exports. We also examine an interaction effect to capture the combined effects of the TEs of a source country and the PRs of destination countries on the bilateral exports of source countries. To check the robustness of our results, we utilise "distance to frontier" as a proxy variable for TEs. We find that our main results are robust to having such variable as a proxy variable for technological efforts.

### 5.1.1 Main Findings of the Dissertation

The main findings of the dissertation are as follows.

A. Finding from the first essay:

I. The synthesis of narrative reviews and meta-regression analysis reveals that country's strength in PRs protection plays a significant role in determining its innovation.

II. With concern to the type of countries, we find strong evidence that PRs policy encouragement of developed countries' domestic innovation; notwithstanding, it dampens developing countries' domestic innovation.

III. We also find that there is a distinction in patent rights' contribution to domestic innovation across developed and developing countries in the existing primary studies.

IV. This study finds that innovation affects export performance across countries. We find strong evidence that developed countries' domestic innovation enhance their exports; however, for developing countries, innovation does not contribute to their exports.

V. It indicates that within developing countries, the level of innovation efforts varies and concomitantly their inability to translate such efforts into exports.

B. Finding from the second essay:

I. We find that strong PRs protection stimulates domestic technological efforts and does indeed spur innovative activities in the source countries, namely, high- and middle-income countries.

II. Furthermore, the empirical result indicates that technological infrastructure index (TII) is a positive and significant determinant of the source country's PRs for both high- and middle-income groups.

III. Technology efforts increase the likelihood that high-income countries become motivated to export high-technology products.

IV. However, for middle-income countries, technology efforts do not contribute to their high-technology exports.

V. We find that destination countries' PRs index is a positively significant determinant of source countries' incentive to export, which highlights that both high- and middle-income countries would export more to countries with a strong PRs protection, controlling for other factors.

VI. In our case, we find that interaction coefficient (between TEs and PRs) is negatively related to exports for the high income countries; that is, holding technological efforts ($TE_s$) constant, a higher level of destination PRs is associated with a lower volume of source exports.

VII. Thus, the market power effect of destination patent rights dominates the market expansion effects on exports in the specific case where the exportable product was propelled by higher technological efforts.

VIII. The interaction coefficient is insignificant for middle-income countries.

C. Finding from the third essay:

I. We find that strengthening countries' TEs increase bilateral exports flow.

II. We find that countries' TEs boost exports along the extensive and intensive margins. Our findings support that both the export margins hold. Countries technological capacity increases the likelihood that countries become motivated to export high technology products along with product quality and export volumes.

III. The importer countries' PRs are positive and significant determinants of extensive export margin. However, this is insignificant for intensive export margin. This result suggests that destination countries' strong PRs work mostly for new trading relationships and product varieties.

IV. Our result indicates that interaction coefficient (between TEs and PRs) is negatively related to exports that is, holding TEs constant, a higher level of destination PRs is associated with a lower volume of source exports. Therefore, where the exportable product was propelled by higher technological efforts, the market power effect of destination PRs dominates the market expansion effects on exports.

V. We find that both importer-and exporter-countries' GDPs have a significant positive impact on exports, and we find a negative influence of bilateral distance.

VI. In case of middle-income countries:

   a. For the extensive export margins, the results indicate that a unit increase in the TEs boosts exports along with the extensive export margin by 30-32%. However, for intensive export margin, it accounts only for 10-11%. Hence, this result depicts that the adoption of technological capacity augments more varieties of products between country pairs for the developing countries.

   b. We find that destination countries' PRs are highly significant with positive signs, notwithstanding, they are insignificant for intensive margin. It establishes that the destination countries' strong PRs motivate developing countries' diversification of product, but it does not influence its exports volume.

VII. In case of high-income countries:

a. For high-income countries, we find that TEs increase exports along with extensive export margin, however, for intensive margin of exports, it is insignificant across the models.
b. We also find a mixed result for destination countries' PRs for developed countries' bilateral exports along with extensive export margin.

VIII. Across different income:

a. We find that TEs positively influence the bilateral export flows across different income combinations.
b. TEs coefficient is highly significant for export flow from developing countries to developed countries (MI-HI). It depicts that the developing countries' high-technology products are more exported to developed countries.
c. We find that high-income countries' TEs enhance bilateral export flows to developing countries (HI-MI), but not to the developed countries (HI-HI).

### 5.1.2 Synthesis of the Empirical Results

This dissertation investigates the impact of patent rights (PRs) on technological efforts of a country and their contribution to high-technology exports at both aggregated and disaggregated levels. We undertake three studies to address the above-mentioned relationships. In the first essay, the synthesis of narrative reviews and meta-regression analysis reveals that innovation determines exports success across countries. By the form of countries, we find strong evidence, which indicates that developed countries' domestic innovation enhances their exports; notwithstanding, for developing countries, innovation does not contribute to their exports.

In the second essay, we study the impact of PRs on the technology efforts of a country and its contribution to high-technology exports. This essay approaches the problem from the source country's perspective to introduce variations in terms of host country factors. Since, developing countries have implemented patent policy changes to comply with TRIPs, a study with focus on such economies is essential. We combine the technological efforts made by countries and their contribution to high-technology exports in order to provide a source and mechanism through which strong PRs contribute to economic growth. We find that TEs contribute to the exports of high-income countries. The results are not as compelling for middle-income countries due to the limited variation in their technology efforts. The influence of technology efforts to exports is quite robust that again highlights the divergence in technology efforts among middle-income countries and concomitantly their inability to translate these same efforts into high technology exports. Though similar evidence emerges regarding the positive influence of PRs in promoting exports. We also examined the interaction between source countries' technology efforts and the destination countries' patent rights environment. The interaction effect has a negative influence on exports in high-income countries, suggesting that stronger destination patent rights enable source country firms to better exploit market power if they possess greater levels of technology.

Further, in the third essay, we undertake disaggregated level study based on the impression that earlier study is based on an aggregate measure of exports (high-technology exports) where extant literature has established the industry specificity of the patent-rights influence on innovation. Hence, we investigate the relationship between technological efforts and export along with margins of exports by utilising disaggregated product-level exports data. Our findings support that both the export margins hold. Countries technological capacity increases the likelihood that countries become motivated to export high-technology products along with product quality and export volumes. Interestingly, for middle-income countries, we find strong evidence that countries' technological efforts augment high-technology products export along with product varieties. We find that both importer-and exporter-countries' GDPs stimulate exports along with trade margins; however, it opposed for bilateral distance. This is one of the most robust empirical finding in the international trade that bilateral trade between two countries is proportional to size, measured by GDP, and is inversely proportional to the geographic distance between them.

We find that middle-income countries' TEs do not contribute to their high-tech exports in the second essay. It indicates that developing countries are not directly involved in innovating and pushing the frontiers of knowledge. Instead, such economies acquire, adapt, and improve the existing technologies from the international technology market. And a study based on granular data of exports will provide deeper insights on the impact of PRs on technological efforts and consequently on the exports. Hence, to attain a better understanding of mechanism through which TEs influence exports, in the third essay, we study the impact of technological efforts on export along with margins of export by using granular data. In specific, for developing countries, we find that TEs contribute their high-tech exports at disaggregated level.

We find that TEs positively influence the bilateral export flows across different income combinations. TEs coefficient is highly significant for export flow from developing countries to developed countries. It depicts that the developing countries' high-technology products are more exported to developed countries. We find that high-income countries' TEs also positively influence bilateral export flows to developing countries, but not to the developed countries. Developed countries are already on the frontier of technology; hence they are not exporting the high-tech exports products as compared to developing countries. The companies for developed countries may be facing stiffer competition for their product which may not be the case in other pairs.

## 5.2 Policy Implications

Based on our results, it has been suggested that policymakers of middle-income countries need to undertake awareness programs for exporters about PRs in other countries. These countries may also support exporters in marketing of the products, brand creation through various schemes, including participation in international trade fairs. Initiatives to reduce the cost of exporters for patenting in different countries will also help exporters to increase the intensive margins. Furthermore, MI as importers of patent-sensitive products from high-income countries, need to be watchful to ensure that market power enjoyed by the HI countries' exporters is not abused.

The changes of PRs since last twenty-five years in many developing countries following the requirement to comply with the TRIPs agreement provided the context to undertake this study. These changes have influenced the level and growth of innovation activity. We find that developing countries appear to be gaining from PRs changes at home, as such changes are contributing towards the technological efforts (TEs) of these countries. And such TEs albeit in specific sectors that are patent-sensitive further contribute towards exports. Considering in few sectors, developing countries have definitely gained from the TRIPs agreement. With the increasing share in the patent-sensitive exports (though on extensive margins only), developing countries are engaged in high technology exports. These economies are benefitting from TRIPs membership.

We find strong evidence from empirical results that middle-income countries should invest in technological infrastructure. This is a crucial driver of innovation and strengthening the technological capabilities, which is critical for achieving countries' economic development.

### 5.3 Major Contributions

This dissertation contributes to the existing literature on PRs, technology, and trade in the following ways. First, we apply PCA to construct the technology effort index, including both input and output indicator of innovation. Second, this study highlights an incremental perspective on an existing channel through which countries gain from PRs, as it influences the technology effort of countries that further stimulates their exports. Third, we approach the problem from the source country's perspective in order to introduce variations in terms of host country factors. Since developing countries have implemented patent policy changes to comply with TRIPs, a study that focuses on such economies is essential. Fourth, we control for an interaction effect, following Shin et al. (2016), to capture the combined effects of the technological efforts of a source country and the patent rights (PRs) of destination countries on the exports of source countries. The difference with Shin et al. (2016) is that we use a different, more comprehensive measure of technology levels (accommodating both input and output measures) and different samples of countries. Fifth, we contribute to the existing literature by examining the role of TEs on the bilateral exports along with margins of trade— extensive and intensive margins. Lastly, we have evaluated the change of bilateral exports based on countries' level of economic and technological development, exploring the variation among countries in terms of income levels and in terms of technological efforts.

### 5.4 Limitations and Directions for Future Research

There are variations in the technology efforts of middle-income countries that are captured through the index. However, the aggregate behavior as reflected by the index needs to be further analysed, which remains for the future work. Second, theories of internalization argue that firms choose among different modes of entry into foreign markets, with exporting and FDI being the key modes. In future research, one can investigate the impact of technological efforts in the source country and higher destination PRs on FDI.

### 5.5. Concluding Remarks

This dissertation attempts to understand the impact of source countries' strong patent rights protection on technological efforts and innovative activities in the source countries. Further, their contribution to high-technology exports at both aggregated and disaggregated levels. Empirical results highlight the implications of strong PRs on the middle-income countries. TEs advocate the product variety along with long-run export growth in order to improve exporters' productivity, improve allocative efficiency, and realise the economic development. These findings have implications for research on the effects of source countries' TEs, and destination countries' PRs on economic development

# APPENDIX-A: Factor score of countries

| High Income Countries | | | | | | Middle Income Countries | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Country** | **PR** | **PnR** | **ScArtcl** | **Researchers** | **R&D** | **Country** | **PR** | **PnR** | **ScArtcl** | **Researchers** | **R&D** |
| **Australia** | 0.44 | 0.38 | 0.5 | 0.38 | 0.5 | Bulgaria | 0.43 | 0.4 | 0.34 | 0.33 | 0.44 |
| Austria | 0.37 | 0.49 | 0.3 | 0.52 | 0.5 | Bosnia and Herzegovina | -0.45 | -0.5 | 0.34 | 0.43 | 0.48 |
| Belgium | 0.44 | 0.38 | 0.11 | 0.47 | 0.45 | Brazil | 0.42 | 0.5 | 0.45 | 0.33 | 0.49 |
| Canada | 0.4 | 0.36 | 0.48 | 0.46 | 0.41 | China | 0.45 | 0.3 | 0.42 | 0.5 | 0.51 |
| Switzerland | 0.43 | 0.27 | 0.42 | 0.43 | 0.7 | Costa Rica | 0.44 | 0.46 | 0.38 | 0.45 | 0.48 |
| Chile | 0.46 | 0.47 | 0.22 | 0.46 | 0.36 | Ecuador | 0.37 | 0.3 | 0.43 | 0.23 | 0.37 |
| Cyprus | 0.38 | 0.29 | 0.39 | 0.37 | 0.37 | Egypt, Arab Rep. | 0.41 | 0.33 | 0.35 | 0.48 | 0.39 |
| Czech Republic | 0.3 | 0.42 | 0.17 | 0.4 | 0.45 | Guatemala | 0.47 | 0.37 | 0.43 | 0.41 | 0.45 |
| Germany | 0.38 | 0.44 | 0.34 | 0.41 | 0.41 | Indonesia | 0.5 | 0.12 | 0.48 | 0.51 | 0.47 |
| Denmark | 0.47 | 0.32 | 0.33 | 0.39 | 0.42 | India | 0.41 | 0.43 | 0.42 | 0.27 | 0.39 |
| Spain | 0.3 | 0.48 | 0.41 | 0.49 | 0.5 | Kazakhstan | 0.41 | 0.29 | 0.39 | 0.44 | 0.36 |
| Estonia | 0.36 | 0.45 | 0.4 | 0.5 | 0.49 | Kenya | 0.42 | 0.45 | 0.44 | 0.34 | 0.41 |
| Finland | 0.45 | 0.49 | 0.27 | 0.47 | 0.5 | Morocco | 0.32 | 0.43 | 0.47 | 0.44 | 0.45 |
| France | 0.4 | 0.41 | 0.38 | 0.43 | 0.37 | Moldova | 0.33 | 0.45 | 0.29 | 0.43 | 0.41 |
| United Kingdom | 0.46 | 0.48 | 0.31 | 0.44 | 0.35 | Mexico | 0.39 | 0.35 | 0.39 | 0.45 | 0.44 |
| Greece | 0.49 | 0.4 | 0.33 | 0.51 | 0.46 | Macedonia, FYR | 0.41 | 0.37 | 0.46 | 0.48 | 0.48 |
| Croatia | 0.38 | 0.42 | 0.38 | 0.28 | 0.42 | Malaysia | 0.47 | 0.39 | 0.41 | 0.46 | 0.48 |
| Hungary | 0.5 | 0.39 | 0.23 | 0.52 | 0.5 | Pakistan | 0.4 | 0.42 | 0.49 | 0.49 | 0.4 |
| Ireland | 0.48 | 0.46 | 0.36 | 0.5 | 0.41 | Panama | 0.32 | 0.38 | 0.49 | 0.45 | 0.39 |
| Iceland | 0.42 | 0.41 | 0.41 | 0.46 | 0.36 | Philippines | 0.38 | 0.47 | 0.44 | 0.41 | 0.45 |
| Israel | 0.47 | 0.49 | 0.39 | 0.29 | 0.42 | Romania | 0.39 | 0.43 | 0.42 | 0.41 | 0.41 |
| Italy | 0.43 | 0.46 | 0.36 | 0.47 | 0.48 | Russian Federation | 0.46 | 0.26 | 0.46 | 0.43 | 0.38 |
| Japan | 0.39 | 0.38 | 0.38 | 0.39 | 0.44 | Serbia | 0.43 | 0.4 | 0.34 | 0.33 | 0.37 |
| Korea, Rep. | 0.44 | 0.37 | 0.36 | 0.42 | 0.43 | Sri Lanka | 0.43 | 0.37 | 0.36 | 0.43 | 0.4 |
| Lithuania | 0.4 | 0.52 | 0.43 | 0.37 | 0.48 | Thailand | 0.41 | 0.41 | 0.43 | 0.47 | 0.48 |
| Latvia | 0.45 | 0.41 | 0.42 | 0.41 | 0.42 | Tunisia | 0.45 | 0.43 | 0.38 | 0.47 | 0.41 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Luxembourg | 0.38 | 0.45 | 0.38 | 0.36 | 0.4 | Turkey | 0.48 | 0.4 | 0.35 | 0.49 | 0.48 |
| Netherlands | 0.38 | 0.39 | 0.36 | 0.49 | 0.34 | Ukraine | 0.49 | 0.45 | 0.16 | 0.41 | 0.39 |
| Norway | 0.42 | 0.44 | 0.4 | 0.4 | 0.38 | South Africa | 0.3 | 0.28 | 0.5 | 0.57 | 0.5 |
| New Zealand | 0.36 | 0.42 | 0.48 | 0.48 | 0.46 | Zambia | 0.42 | 0.46 | 0.43 | 0.36 | 0.46 |
| Poland | 0.39 | 0.44 | 0.29 | 0.4 | 0.45 | | | | | | |
| Portugal | 0.46 | 0.36 | 0.41 | 0.49 | 0.48 | | | | | | |
| Singapore | 0.45 | 0.44 | 0.36 | 0.49 | 0.47 | | | | | | |
| Slovak Republic | 0.43 | 0.41 | 0.36 | 0.47 | 0.36 | | | | | | |
| Slovenia | 0.37 | 0.45 | 0.36 | 0.51 | 0.5 | | | | | | |
| Sweden | 0.44 | 0.47 | 0.29 | 0.36 | 0.36 | | | | | | |
| United States | 0.42 | 0.41 | 0.42 | 0.26 | 0.38 | | | | | | |

Notes:

Middle-income economies are those whose GNI per capita is more than $1,026, but less than $12,475 and High-income economies are those whose GNI per capita is $12,476 or more (World Bank 2016).

PR: Number of the patent application by residents

PnR: Number of the patent application by non-residents

ScArtcl: Scientific and technical journal articles

Researcher: Researchers in R&D per billions

R&D: R&D expenditure as % of GD

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