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PATENT PROTECTION, TECHNOLOGICAL EFFORTS, AND EXPORTS: AN EMPIRICAL INVESTIGATION

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ABSTRACT

This study proposes an incremental perspective concerning the channel through which countries gain from strengthening patent rights (PRs). We hypothesize that the patent rights influence the technological effort of a country that further stimulates its exports. It is not evident in previous studies how the changes in innovativeness translate into economic growth. In this paper, we study the impact of PRs on the technology efforts of a country and their contribution to high-technology exports. We combine the technology efforts 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. This study adds to the literature by computing a technology effort index via principal components analysis to quantify the technological efforts made by a country, which we then use to measure its contribution on exports. Using panel data analysis on 67 countries from 1996-2014, this paper finds that patent rights influence the technological effort of a country that further stimulates its exports. This finding has implications for the role of the patent system in technological development and export orientation, both of which are important factors in economic growth. 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. The results also demonstrate a positive relationship between a destination country's patent protection and export flows, which may be reduced if the technological efforts of a source country enable exporters to exercise market power. This result indicates that 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.

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INTRODUCTION

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. In this paper, we focus on the influence of patent protection on technological efforts that augment the export capacity of countries. Developing economies motivated to become internationally competitive make extensive technological efforts to raise their export performance. This may necessitate moving beyond trade in primary and low technology goods to high-technology products (Lall, 2000; Srholec, 2007). Indeed, the contribution of high-technology exports to economic growth has been empirically documented in various studies (Srholec, 2007; Falk, 2009). However, existing evidence on the role of technology and patents in developing country exporting is inconclusive. 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[1]. Other countries 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[2].

With the aim of enhancing economic growth through technological progress, policymakers have undertaken major initiatives like patent reforms. 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. 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. Ongoing studies explore the impact of PRs either on economic growth or on innovativeness through research and development expenditure (R&D) and patenting[3]. It is not evident in these studies how the changes in innovativeness translate into economic growth. In this paper, we study the impact of PRs on the technology efforts of a country and their contribution to high-technology exports. We combine the technology efforts 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.

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 utilizes 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 utilize high-tech exports because high-tech products are used to represent the technological intensity of exports (Srholec, 2007). We use a panel dataset consisting of 67 countries for the period 1996-2014. Our paper contributes to the existing literature on PRs, technology, trade and economic development 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 provides an incremental perspective on an existing channel through which countries gain from PRs, namely the increase in the technology efforts of countries that further stimulate their exports. Lastly, we approach the problem from the source country's perspective in order to introduce variations in terms of host country factors.

The next section sets the background by reviewing existing evidence on technological efforts, PRs, and exports, and by describing their inter-relationship. Section 3 provides details on the variables, data sources, and the model. The empirical results are presented in section 4. Section 5 summarizes and concludes the paper.

PREVIOUS LITERATURE

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, for 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, technological capabilities (Bhaduri and Ray, 2004) or 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,[4] and 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 concept of technological capability[5]. 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 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[6]. 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 (Gould and Gruben, 1996; Ginarte and Park, 1997; Park, 2008; Chen and Iyigun, 2011).

PRs protection should not only influence the technological efforts of a country but trade flows among countries. Many theoretical studies conclude 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. 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.

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 PR and exports conditioned by the technological efforts of the source country. From the above discussions, we present two hypotheses regarding the effects of technology 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.*

EMPIRICAL MODELS, VARIABLES, AND DATA

For empirical purposes, we propose to use a panel data technique to analyse the relationship among PRs, technology efforts, and exports. This study considers the following equations:

$$\mathrm{TE}_{\mathrm{it}} = \mathrm{C}_1 + \beta_{11}\mathrm{PR}_{\mathrm{Sit-1}} + \beta_{12}\mathrm{TII}_{\mathrm{Sit-1}} + \beta_{13}\mathrm{Size}_{\mathrm{Sit}} + \beta_{14}\mathrm{Edn}_{\mathrm{Sit-1}} + \beta_{15}\mathrm{Capital}_{\mathrm{Sit}} + \beta_{16}\mathrm{OPN}_{\mathrm{Sit-1}} + \mathrm{u}_{\mathrm{it}} \tag{1}$$

$$\mathrm{EXP}_{\mathrm{it}} = \mathrm{C}_1 + \alpha_{11}\mathrm{TE}_{\mathrm{Sit-1}} + \alpha_{12}\mathrm{GDP}_{\mathrm{Dit-1}} + \alpha_{13}\mathrm{OPN}_{\mathrm{Dit-1}} + \alpha_{14}\mathrm{EXR}_{\mathrm{Sit-1}} + \alpha_{15}\mathrm{PR}_{\mathrm{Dit-1}} + \alpha_{16}\mathrm{TE}_{\mathrm{Sit-1}} * \mathrm{PR}_{\mathrm{Dit-1}} + \epsilon_{\mathrm{it}} \tag{2}$$

Where *i* denotes country, and *t* years. Subscript D stands for destination country and S for source country. As dependent variables, TE denotes the technology effort index and EXP high technology exports as a percentage of manufactured exports. For independent variables, we build on the literature to include control variables and 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 the variables. Continuing with our definitions, PR refers to the patent rights index (as used before) and TII the countries' technological infrastructure index. Size refers to government consumption expenditure as a percentage of GDP, Edn secondary school enrolment (% gross), Capital gross capital formation (% of GDP), OPN trade openness index, GDP the gross domestic product per capita growth (% annual), and EXR 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 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. We estimate both equations (1) and (2) for a full sample of our countries[7], and then estimate them by subgroups of high-income and middle-income countries, as classified by the World Bank (2016)[8]. These split samples help us measure the varying effects of technology efforts, exports, and PRs by income group.

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 index by principle component analysis. Five variables are included 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. Scientific and technical journal articles and patents capture output produced through R&D. A country's production of new technology is captured by its patents and it is an important indicator of the technological activities of firms in the country (Basberg, 1987; Archibugi and Planta, 1996). A complementary relationship exists 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). The technology effort index ranges from 0 to 5.37 where higher values indicate more intensive innovation activity.

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 (PRs) across countries[9]. In equation (1), we use the source country's PRs index and in equation (2), we use a weighted average of destination countries' PR 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 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 population with access to electricity. We took the average value of the three standardized variables to construct the TII index.

Secondary school enrolment (% gross) is assumed to capture the inputs into the technological efforts of a country (Lall, 2000). Gross capital formation (% of GDP) is used to capture the role played by physical capital in innovation development (Funke and Strulik, 2000). We take 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 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). Government Size as measured by government consumption expenditure as a percentage of GDP can capture public goods inputs for private production (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.

DATA

Table1 provides variable definitions, descriptive statistics, and data sources. This study conducts panel data analysis on 67 countries and panels of five-year averages during 1996-2014.

Table 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 PR index of the source country is 3.68 (out of 5). Table 2 shows the correlation matrix, indicating that the source countries' PRs protection and technology infrastructure are positively correlated with technology effort. Table 3 shows the average value of technology efforts index, PRs and high technology exports by period. As expected, there is a closing of gap between high income and middle-income countries' average PR values due to compliance with TRIPS.

TABLE 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	5.37	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)	191.1	1000.2	0	9495.9	WDI
$OPN_{S\ t-1}$	Trade openness as exports plus imports divided by the GDP of the source country	0.86	0.99	0	8.22	UN Comtrade, WITS, WDI
$OPN_{D\ t-1}$	Weighted average of the trade openness of the top 20 trading partners among the destination countries	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 2: CORRELATION MATRIX

Variables	TE	PRs_S $_{t-1}$	TII $_{t-1}$	Size	Edn $_{t-1}$	capital	OPN_S $_{t-1}$	Exports	PRs_D $_{t-1}$	TE*PR	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*PR	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: AVERAGE VALUE OF TI, PR 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)

Notes: Numbers in parentheses are standard deviation

Figures 2 and 3 plot the relationship between patent rights protection and technological efforts, by income group. While there is a positive trend in both samples, efforts are relatively lower in middle-income countries than in high-income countries.

FIGURE 1: ALL COUNTRIES

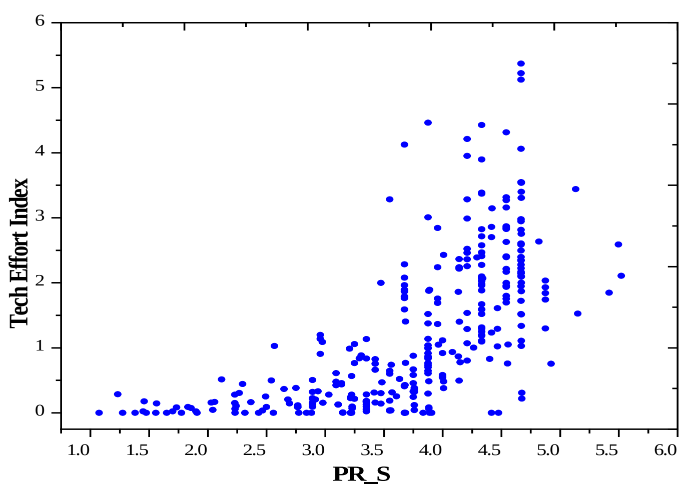


FIGURE 2: HIGH-INCOME COUNTRIES

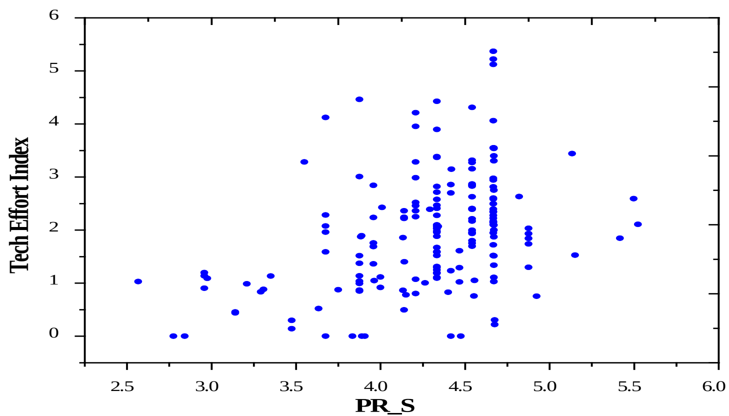
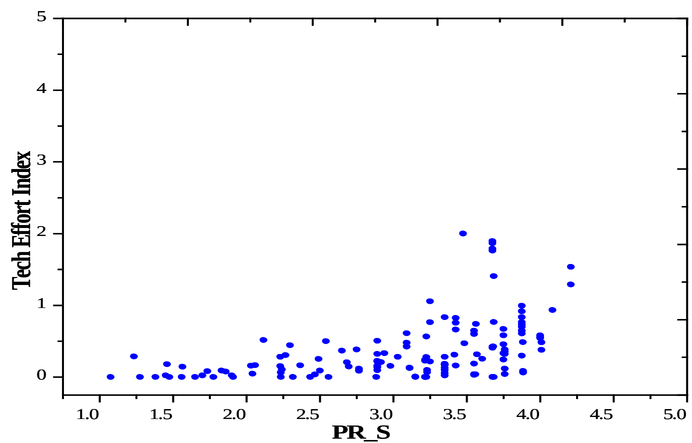


FIGURE 3: MIDDLE-INCOME COUNTRIES



EMPIRICAL RESULTS

Tables 4 and 5 present results for all our countries, and by subgroups: high income and middle-income countries. We report either FE or RE based on the Hausman (1978) 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.

EMPIRICAL RESULTS OF TECHNOLOGY EFFORTS EQUATION

Table 4 reports the empirical results of the technology effort equation (i.e. equation 1). The result shows that the coefficient of PRs index is positive and statistically significant at conventional levels for all country groups under RE estimation. This 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 (TII) is a positive and significant determinant in all the equations. The results for both PRs and TII variables remain unchanged when the control variables are added, except for the PR variable under RE estimation for high-income countries. This can be due to the high level of PR 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' technology efforts. In terms of other control variables, we do not find significant influences of the other factors considered. 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 enrolment. A more refined proxy for higher education's availability, cost, and accessibility may be a more appropriate variable to use in future to capture human capital.

Dependent Variable: Tech Efforts Index	All Countries	High-Income	Middle Income

TABLE 4: RESULTS OF TECHNOLOGY EFFORT EQUATION (EQUATION 1)

	1	2	3	4	5	6
PR_S $_{t-1}$	0.05	0.05	0.32**	0.13	0.08**	0.09**
	(0.05)	(0.06)	(0.15)	(0.15)	(0.03)	(0.04)
TII_S $_{t-1}$	2.99***	2.27***	3.14***	2.11***	1.2***	1.19**
	(0.38)	(0.46)	(0.57)	(0.65)	(0.3)	(0.5)
Size_S		(0.0008)		0.01		0.01*
		(0.01)		(0.02)		(.008)
Edn_S $_{t-1}$		-0.0009		-0.0004		0.0007
		(0.002)		(0.003)		(0.001)
Capital_S		-0.01		0.01		0.002
		(0.008)		(0.01)		(0 .008)
OPN_S $_{t-1}$		0.59***		1.13***		0.01
		(0.18)		(0.35)		0.16
Constant	-0.52**	-0.23	1.51***	-1.96	0.29***	-1.4
	(0.20)	(0.89)	(.54)	(1.92)	(0.11)	(0 .6)
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	0.40	0.47	0.35	0.38
Observation	252	229	140	136	112	93

Notes: Numbers in parentheses are standard errors.

, ** and * denote that coefficient is significant at 10, 5 and 1 percent levels respectively.*

EMPIRICAL RESULTS OF EXPORTS EQUATION

The empirical results of the export equation are presented in Table 5. The technology effort index is highly significant with a positive sign in high income countries. This result implies that 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. Thus, this result indicates patent rights help play a significant role in the economic development of economies by helping to draw high technology products to both high- 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 earlier that the relationship between the PRs of destination countries and the trade flows of source countries is ambiguous. 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 spurs exporters to enhance the volume of exports. We find in our case the interaction coefficient is negatively related to exports of high-income countries: holding technological effort (TE) constant, a higher level of destination PRs is associated with a lower volume of source exports. Thus, in our case, what we reveal is that 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. That is, 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.[10] 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 technology 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 effect of destination patent protection and source country technology level on source country exports, holding other determinants constant.

Using estimates from column 4 of Table 5, we find $\frac{\partial EXP}{\partial PR_D} = 7.41 - 5.6 \text{ x } TE_S$ 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.[11]

TABLE 5: RESULTS OF THE EXPORT EQUATION (EQUATION 2)

Notes: Numbers in parentheses are standard errors.

, ** and * denote that coefficient is significant at 10, 5 and 1 percent levels respectively.*

DISCUSSIONS

We have empirically shown 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. 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. 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

Dependent Variable: Exports	All countries		High Income		Middle Income	
	1	2	3	4	5	6
TE_S_{t-1}	15.44***	13.89***	27.80***	24.35***	15.546	15.82
	(5.49)	(5.71)	(7.89)	(8.27)	(18.07)	(18.59)
PR_D_{t-1}	3.47***	3.71***	7.90***	7.41***	5.05**	5.02**
	(1.4)	(1.47)	(2.92)	(3.03)	(2.62)	(2.75)
$TE_{t-1}*PR\_D_{t-1}$	-3.75***	-3.20***	-6.57***	-5.6***	-4.07	-4.17
	(1.26)	(1.32)	(1.83)	(1.94)	(4.70)	(4.84)
GDP_D_{t-1}	0.05	0 .33		0.44		.01
		(.43)		(0.61)		(0.76)
OPN_D_{t-1}		-4.05		-3.27		-.65
		(3.02)		(6.23)		(4.06)
EXR_S_{t-1}		-0.0004		-0.002		-0.0003
		(.0006)		(0.004)		(0.0007)
Constant	0.61	1.29	-17.14	-14.25	-5.24	-4.74
	(5.86)	6.31	(12.29)	(13.15)	(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	0.05	0.06	0.04	0.05	0.04	0.06
Observations	259	232	146	122	113	110

relatively low that the technological intensity of their high-tech products does not condition the response of their exports to foreign patent regimes.

CONCLUSIONS

This study constructed a technology effort index using principal component analysis using both input and output indicators of innovation and showed that it is determined by patent rights and that, in turn, it determines export capacity. To date, previous work has not constructed such a comprehensive index of technology effort, nor has it measured its impact on facilitating the effects of patent laws on exporting.

We find that technology efforts, in particular, 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.

These findings have implications for research on the effects of patent reform on economic growth. We identified a channel whereby patent protection affects export orientation through stimulating the technological efforts of exporters.

ENDNOTES

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India's exports of generic drugs provide an example of such exported products.

[2]Chinese dominance in the patenting and exporting of solar panels is a case in point.

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

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

[5]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.

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

[7]67 countries are included in this study based on data availability.

[8] 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).

[9]The index ranges in value from 0 to 5, with higher values reflecting stronger levels of protection.

[10]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.

[11]We have performed robustness checks of the results using different econometric models and variables. Our results remain relatively intact and can be made available upon request.

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