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DO STRONGER INTELLECTUAL PROPERTY RIGHTS INDUCE MORE INNOVATIONS? A CROSS-COUNTRY ANALYSIS

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Abstract

This paper examines the role of IPRs protection on stimulating innovations across countries. To consider the possible difference in the relationship between IPRs and innovations for countries of various development degrees, we employ the technique of panel threshold model to proceed with empirical estimates. Based on a panel dataset of 42 countries over the 1997-2006 period, results show that stronger IPRs protections enhance innovations using conventional panel data model. After considering the threshold effects, IPRs protection remains a significantly positive influence on innovations for high-income countries, but it has no effect on fostering innovations for non-high-income countries.

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I. *Introduction*

In a world toward free international trade, foreign direct investment (FDI), and

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international exchange of knowledge, a country's technological progress depends not only on domestic R&D capital but also on foreign R&D capital (Coe and Helpman, 1995). It reveals that developing countries can promote their technological capability through learning and assimilating foreign knowledge rather than in-house R&D, inducing them to create a weak IPRs regime favoring knowledge spillover and imitation. Alternatively, to strengthen and harmonize the means for protecting IPR to cope with globalization, industrial nations placed IPRs at the center of the agenda during the negotiations covering the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). Finally, the Agreement of Trade-Related Intellectual Property Rights (TRIPS), administered by the World Trade Organization (WTO), was established in 1995 to set minimum standards of intellectual property rights (hereafter, IPRs) protection for each WTO member.

Indeed, how to best protect IPRs has stimulated much discussion in the arena of international economic policies related to trade, FDI, technology transfer, and innovations during the past decade.[1] Individual countries have tried to construct an adequate legal system of IPRs that can create an environment conducive to technological progress, depending on their own economic and technological conditions. Therefore, IPRs laws and the enforcement of existing laws differ substantially across countries. Do stronger IPRs create a favorable environment for innovations and then induce more innovations? The divergence for the effects of strengthening IPRs on innovations between North and South countries seems to have widened in recent years. Advanced countries often contend that stronger IPRs protection is good even for developing countries, because it can attract more FDI and technology transfer and thus contributes to host countries' technological capability and stimulates more domestic innovations (Maskus, 2000). Alternatively, some developing countries argue that an extension of international IPRs harms their technological progress and prefer to establish weaker IPRs regimes favoring technological diffusion through imitation and acquisition from abroad.[2] Forero-Pineda (2006) traces related debates regarding IPRs and concludes that the negative effects of the trend toward stronger IPRs of the less advanced and developing countries have become more apparent and understandable in some cases.

The topical debate on the efficacy of strengthening IPRs on promoting national innovations has attracted wide attention among theoretical economists - that is, whether stronger IPRs induce more innovations, depending on the degree of economic development. Recent theoretical articles have used more sophisticated modeling frameworks to explore this issue and reached mixed results, suggesting the need of empirical works to provide a clearer picture. However, empirical studies examining the influence of strengthening IPRs protection on innovations across countries remain rare. In particular, there are few papers exploring this issue using data for the post-TRIPs period, given the topical debate on IPRs between developed and developing countries. It inspires the main purpose of this study that examines the role of IPRs protection in fostering innovations across countries in the post-TRIPs period.

Specifically, the point whereby developing countries claim that a weak IPR regime is favored for fostering innovations is not well examined. It is well known that biases appear when parameter heterogeneities among cross-sectional units are ignored (Hsiao, 2003). In a

[1] For a survey of the macroeconomic effects of intellectual property rights, please refer to Chu (2009).

[2] Forero-Pineda (2006) identifies some effects of the global trend towards stronger protection of intellectual property rights on developing countries, and traces related debates.

patent production function approach, the assumption of a common elasticity of output with respect to IPRs protection is a doubtful one for the cross-country panel study, given that developing countries claim a negative effect. However, existing studies based on the patent production function approach generally specify country heterogeneity only using random or fixed individual effects (Furman *et al*., 2002; Schneider, 2005), but do not well deal with the potential difference in the IPRs–innovations nexus across various national degree of economic development. Hansen (1996, 1999 and 2000) develops the panel threshold model that allows the sample data to determine the number and location of the thresholds. This econometric technique enables us to test for thresholds in the IPRs – innovation nexus and then add new evidence to this international debate.

This paper empirically investigates the role of IPRs protection in innovations across countries, attempting to further the literature in three ways. First, most existing studies that examine the relationship between IPRs and innovations focus on a single country, such as Japan and the U.S., while few studies provide cross-country evidence. This cross-country study provides new evidence and lends implications to international economic policies, such as TRIPs. Second, this paper uses a panel dataset of 42 countries during 1997-2006 that contains both developed and developing countries for the post-TRIPs period. Crucially, to obtain robust estimates, this study adopts various measures of IPRs protection indices. This study not only adopts the Ginarte-Park index, but also employs longitudinal and consistent IPRs indices surveyed by the International Institute for Management Development (IMD) and World Economic Forum (WEF) to investigate the dynamic process between IPRs and innovations. The protection of IPRs is inherently a dynamic process, involving both a secular evolution within one country over time and the need for new standards of protection, but previous empirical works use only cross-sectional data rather than panel data due to the lack of a persistent and consistent index of IPRs, especially for years after 1995 when the TRIPs was implemented. Even though these IPRs indices are not perfect, they provide consistent year-by-year indices of IPRs protection for international comparison. Third and most crucially, as argued by developing countries and theoretical predictions that a stronger protection of IPRs is perhaps harmful rather than helpful for technological progress, it indicates that the role of strengthening IPRs on impacting innovations may vary among countries with different economic development degree. To explore the potential difference in the innovation effect of IPRs strength between developing and developed countries, this paper adopts the technique of the panel threshold model to conduct the empirical estimation.

The remainder of this paper is organized as follows. Section II briefly reviews both theoretical and empirical linkages between IPRs protection and innovations for developing countries. Section III presents the empirical models for estimating the effect of IPRs protection based on the framework of the threshold regression approach. Moreover, the utilized dataset is briefly described. Section IV reports the empirical results, including panel regression with and without considering the threshold effect. Section V implements some further robustness check. The final section summarizes concluding remarks and policy implications.

II. *Literature Review*

Does stronger IPRs protection is beneficial for developing countries to upgrade technological ladder? This debatable issue has recently attracted an emerging amount of theoretical studies that adopt the imperfect competition model to derive static and dynamic equilibrium of innovations under assumptions of various degrees of IPRs protection and knowledge spillover. McCalman (2001) claims that the move toward stronger IPRs in developing countries may work against national economic interest, transferring rents to multinational corporate patent holders headquartered in the world's most advanced countries. Glass and Saggi (2002) develop a product cycle model with endogenous innovation, imitation, and FDI to determine how stronger IPRs protection in the South affects innovation. They find that the increased difficulty of imitation due to stronger IPRs generates resource waste and imitation disincentive effects that reduce innovations.

Grossman and Lai (2004) argue that harmonized patent rights are unlikely to benefit developing countries unless they receive additional compensation. However, the work carried out by Chen and Puttitanun (2005) shows that innovations in a developing country increase through its IPRs, and a country's IPRs can depend on its level of development non-monotonically, by first decreasing and then increasing. It highlights the disproportional importance of IPRs on innovations, depending on a country's degree of economic development. Parello (2008) examines how stronger IPRs protection in the South affects the processes of R&D investment, technology transfer, and skill accumulation. He finds that stronger IPRs protection has only a temporary impact on the innovation rate, while it has a negative impact on the long-run imitation rate.

Bessen and Maskin (2009) argue that when innovations are sequential, patent protection is not as useful for encouraging innovation. They suggest a cautionary note about IPRs protection. The reflexive view that "stronger is better" could well be too extreme; rather, a balanced approach seems called for. The ideal patent policy limits "knock-off" imitation, but allows developers who make similar, but potentially valuable complementary contributions. Systems that limit patent breadth, such as in the Japanese system before the late 1980's, may offer a better balance. In this sense, a weaker IPRs protection seems to be beneficial for technological progress for developing countries. Recently, Furukawa (2010) and Gangopadhyay and Mondal (2012) argue that the relationship between IPRs protection and innovation can be inverted-U-shaped, implying that stronger protection of IPRs may discourage innovation

Compared with the plenty of theoretical works, empirical studies examining the IPRs – innovations nexus for developing countries remain rare and present ambiguous outcomes. Specifically, they generally utilize data for the pre-TRIPs period and employ conventional panel data model to carry out empirical estimation. Varsakelis (2001) firstly uses a cross-sectional data of 50 selected countries to examine the impact of a patent protection framework on R&D investment and concludes that countries with a strong patent protection framework invest more in R&D. Furman *et al*. (2002) find that the production function for international patents is well characterized by the extent of IPRs protection. In other words, the pro-patent policy hypothesis argues that a country with a stronger patent protection will potentially spur firms to have a more aggressive propensity on patenting.

Schneider (2005) examines the role of high-technology trade, IPRs, and FDI in determining a country's rate of innovation and economic growth. His empirical results by using a panel dataset of 47 developed and developing countries from 1970 to 1990 show that IPRs has no significantly positive influence on innovations for the whole sample, but this impact is positive and significant for developed countries. The similar result is also found in Kim *et al*.

(2012). Using a panel dataset of over 70 countries, they find patent protection is an important determinant of innovations in developed countries, but not in developing countries.

Qian (2007) analyzes the role of patent reform on pharmaceutical innovation. His cross-country study suggests that strengthening IPRs has a significantly positive impact on pharmaceutical patents, because the pharmaceutical innovation is essentially highly sensitive to the protection of intellectual property.[3] More recently, Hudson and Minea (2013) argue that the effect of IPRs on innovation is more complex than previously thought. It displays important nonlinearities depending on the initial levels of both IPRs and per capita GDP, implying that a single global level of IPRs is in general sub-optimal

Drawing from the above discussions, limited empirical cross-country studies suggest the need of new evidence. Despite this study is similar to existing literature, it contributes to this line of research by dealing with the unsolved drawbacks in previous studies. First is examining the thresholds in the relationship between IPRs strength and innovation. It can effectively differentiate the possible difference in the innovation effect of IPRs between developed and developing countries. Second, as various IPRs protection indices are constructed by focusing on the coverage of IPRs laws or the enforcement strength, suggesting individual index has its advantages and disadvantages. This study adopts various measures of IPRs protection indices to implement empirical estimations, in order to obtain reliable and robust results.

III. *Model Specification, Methodology, and Data*

1. Empirical Specification

Adopting the knowledge production function developed in Pakes and Griliches (1980) and Hausman *et al*. (1984), a country's patent production is assumed to be a function of its R&D expenditure, R&D researchers, and other determinants as specified as following:

$$P_{it} = AR_{it}^{\alpha} L_{it}^{\beta} e^{e} \tag{1}$$

The model is expanded to include other variables that may influence patenting P (proxy for innovation). The multiplier A is the efficiency of knowledge production due to internal and external factors: especially the degree of IPRs protection and the difference in patenting due to countries' specific characteristics.

Taking the logs of both sides of Equation (1) yields the following log-linear equation

$$\ln P_{it} = \alpha \ln R_{it} + \beta \ln L_{it} + \sum_{c} \alpha_c \ln X_{it} + \theta \ln IPRP_{it} + \varepsilon_{it} \tag{2}$$

where R_{it} is the country's R&D expenditure, L_{it} is the number of R&D researchers in a country, Xs are vectors of country-specific characteristics, the term IPR is a measure of the strength of IPRs, and ε is an error term. Combining the factors we are concerned with, the empirical

[3] Another line of research using firm-level data within one country overall reach the similar outcome that stronger IPRs protection does matter to innovations for non-developed countries. For instance, Aboites and Cimoli (2002) analyze data from Mexico and argue that the use of patents is a weak incentive for local innovation. Yang (2008) finds a short-term positive effect of patent reform on fostering innovations in Taiwan.

specification is as below:

$$\begin{aligned}\ln PAT_{it} = \beta_0 + \beta_1 \ln RD_{it} + \beta_2 \ln RERD_{it} + \beta_3 \ln OPEN_{it} + \beta_4 \ln POP_{it} \\ + \beta_5 \ln EXP_{it} + \beta_6 MANU_{it} + \beta_7 \ln IPRP_{it} + \varepsilon_{it}\end{aligned} \tag{3}$$

The dependent variable *PAT* is the number of patent applications from country *i* in the U.S. In the empirical literatures of innovation and IPRs, resident patenting and US patent application are both conventional proxy of innovation activity (Park, 2008). Owing to the differences in requirement of novelty across countries, using national patents suffers the problem of "home-country-advantage-effect", leading to distorted information regarding innovations.[4] Therefore, we use the number of US patent applications as the indicator of innovations.

Although the drawbacks of using patent counts as indicator of innovation are widely discussed, U.S. patents are one of the clearest indications of innovation performance, because they can be treated as "new-to-the-world" innovations (Furman *et al*., 2002). Crucially, the international patenting function proposed by Eaton and Kortum (1996) assumes the number of US patents is a proportion of domestic innovation, suggesting it is one of feasible proxies being used to test the impact of the national IPRs on national innovation. Existing cross-country studies, such as Schneider (2005) and Kim *et al*. (2012) have been adopted US patent as the proxy of innovations to examine the influence of IPRs protection on domestic innovations.[5]

Regarding the explanatory variables, Research and Development (R&D) expenditure, in logarithm (ln*RD*), is the key input in the patent production function. The literature focusing on the R&D-patent relationship has addressed the question of whether one could measure the lag structure of R&D expending, while concluding that the lag structure is very poorly identified.[6] Therefore, the study includes only the contemporaneous level of R&D spending in the model, following Hall and Ziedonis's (2001) specification. The intension of human capital on R&D is also a critical variable of innovation output. *RERD* denotes the number of R&D researchers per million populations in a country, and it servers as a proper proxy for the input of human capital in innovation (Schneider, 2005).

OPEN denotes the degree of openness, which is measured as the ratio of trade to GDP. It is a policy variable that captures the effect of international spillovers in the domestic economy through trade (Varsakelis, 2001). Moreover, Furman *et al*. (2002) treat openness as one of policy choices that particularly affects the environment for innovative activity, because openness enforces a country to face the international competition. Therefore, openness is expected to have a positive influence on innovations. The term *POP* is a country's population that represents the base for innovation. Teitel (1994) identifies population as the major determinants of the R&D investment, as it represents the market size for new products. On the other hand, Furman *et al*. (2002) treat population as the scale of resources (workers) potentially available for innovative activity. Therefore, a country with more population tends to positively relate to

[4] For example, the utility model and design patents (more than 90% of patents granted in China) do not require substantive examination in order to be granted in China.

[5] US patents can serve as an adequate proxy of domestic innovation basing on the assumption that there is a same proportion of patenting propensity toward US. However, this assumption generally does not hold.

[6] For example, see Hausman *et al*. (1984) and Cincera (1997). They find that the estimate of the sum of R&D lag coefficients is roughly the same as the estimated coefficient of contemporaneous R&D as no lags are included.

innovations. Terms *EXP* denotes a country's exports to the U.S. Outbound patenting is highly relevant to trade with patenting destination (Eaton and Kortum, 1996; Yang and Kuo, 2008), suggesting that exports have a positive influence on the count of U.S. patents. The reason is intuitive that, as firms increase exports to foreign markets, they seek shelters from imitation and competition in the local markets, resulting in a surge of patents. Term *MANU* is the output ratio of the manufacturing sector to GDP. Qian (2007) suggested that the effect of IPRs would be different depending on technological fields. As patents are generally granted to "functions" and "products" which are used and produced by the manufacturing sector, we thus adopt this variable to control the variations of industry structures across countries.

The most important variable we concern is the degree of intellectual property rights protection (*IPRP*). How does one measure the national difference in IPRs protection? Unlike most previous studies that adopt the IPRs index developed by Ginarte and Park (1997), this study takes alternative indices surveyed by both IMD and WEF. The main reason is that the dataset we use encompasses the 1997-2006 period, while the Ginarte-Park index is not available for each year during this period.[7] Both IMD and WEF index can provide longitudinal and consistent measures of IPRs strength. IMD's IPRs index measures the degree of IPRs protection of various countries by querying the question: "Whether intellectual property rights are not adequately enforced or are adequately enforced?" A representative sample of respondents answers this question and gives a score ranging between 0 and 10.[8] A higher index value denotes a stronger level of protection. Similarly, WEF index reported by World Economic Forum is a consecutive and consistent index for a larger pool of countries. The question in the WEF survey is "Intellectual property protection in your country (1= is weak or nonexistent, 7= is equal to the world's most stringent).[9] The WEF IPRs index ranges between 1 and 7 that a higher value represents a stronger IPRs protection. Actually, both the IMD and WEF indices have been adopted in previous studies and are proved to be highly correlated with he Ginarte-Park index (Nunnenkamp and Spatz, 2003). If stronger IPRs really induce more innovations, we can expect that the coefficient of *IPRP* should be significantly positive.

2. Estimation Techniques and Data

As is common in the specification of panel data model,[10] we allow for the existence of individual effects which are potentially correlated with the right-hand side regressors, such that:

$$\varepsilon_{it} = u_i + v_{it} \tag{4}$$

[7] The Ginarte-Park IPRs index is available for years before 1990 and then Park (2008) updates the index for years 1995, 2000, and 2005.

[8] IMD surveys local and foreign enterprises operating in a given economy, and nationals as well as expatriates. The distribution of survey reflects a breakdown of industry by sectors: Primary, Industry/Manufacturing and Services/ Finances. In order to be statistically representative, they select a sample size which is proportional to the GDP breakdown of economic sectors of the economy.

[9] The details regarding how this indicator was constructed, who responded to the IMD survey, what was the sampling strategy etc, please see the Technical Notes and Sources of Global Competitiveness Report.

[10] As the minimum number of US patents is 3, this study therefore adopts conventional panel data model rather than count panel data model. Actually, results obtained from linear panel model and count panel data model are quite similar.

Here u_i is a country-specific effect that corresponds the permanent, unobserved heterogeneity across countries but not within a country over time, and v_{it} is a "white noise" error term and it is assumed to be independent across countries and over time. Using a "within firm" panel estimator, fixed effect (FE) or random effect (RE) technique, to eliminate the individual effect is a standard estimation method.

As the role of IPRs on innovation may differ among different groups of countries, previous papers generally use sub-sample of developing countries and developed countries to separately estimate the parameters of the IPRs' effects on innovations. However, separating the sample into two sub-groups using some economic indicators is subjective, as one cannot know what degree of economic development is the threshold. Moreover, the threshold might exist depending on one country's R&D activity rather than per capita GDP.

The threshold model developed by Hansen (1996, 1999, and 2000) provides as an excellent alternative approach. This approach allows for testing the existence of thresholds and if so, it allows observations to fall into regimes, depending on an unknown value of an observed variable. That is, the panel threshold model has advantages of avoiding the subjective country classification and using econometric approach to search the threshold point based on data. According to Hansen's (1999) specification, a single threshold model is as follows:

$$y_{it}=u_i+\beta_1' x_{it} I(q_{it}\leq\gamma)+\beta_2' x_{it} I(q_{it}>\gamma)+\varepsilon_{it} \tag{5}$$

where I (*) is the indicator function and q is the threshold variable. When a significant threshold value γ_1 is detected, the observations can be divided into two regimes, depending on where the threshold variable q_{it} is smaller or larger than the threshold γ_1. The two regimes of countries are distinguished by different slopes β_1' and β_2'.

In the case of two thresholds, the double thresholds model takes the following form:

$$y_{it}=u_i+\beta_1' x_{it} I(q_{it}\leq\gamma_1)+\beta_2' x_{it} I(\gamma_1\leq q_{it}\leq\gamma_2)+\beta_3' x_{it} I(\gamma_2<q_{it})+\varepsilon_{it} \tag{6}$$

where γ_2 is the second threshold and the thresholds are in sequence so that $\gamma_1<\gamma_2$. Intuitively, the model can be extended to the multiple thresholds model. Hansen (1999) recommends an estimation of threshold value by the least square method, which involves searching over distinct value of q_{it} for the value of threshold(s) at which the sum of squared errors is smallest.[11]

To examine the role of IPRs protection in spurring innovations across countries, especially for the period when the TRIPs has gone into effect, our dataset includes 42 countries over the 1997-2006 periods. The number of countries is mainly subjected to the fit in with the countries included in IMD and WEF indices. Data on IPRs indices are obtained from various issues of annual report of IMD and WEF as well as the Table 1 in Park (2008). Other variables, excluding country's exports to the U.S., are drawn from the World Bank's World Development Indicators. The export variable is collected from the database of Taiwan institute of economic research. Table 1 summarized the definition, basis statistics, and data sources of variables.[12]

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[11] Please refer to Bai and Perron (1998) and Hansen (1999) for the statistical issues of estimation, testing and construction of confidence intervals for the threshold parameter.

[12] The correlation matrix of variables is provided in the Appendix Table 1.

Table 1. Variable Definition, Basic Statistics, and Data Sources

Variable name	Definition	Mean	Standard Deviation	Data Source
PATA	Number of patent application in the U.S	3,364.758	9,922.537	Calendar Year Patent Statistics, U.S Patent and Trademark Office
PATG	Number of patent granted in the U.S	1,729.203	5,389.604	
IMD-IPR	The degree of IPR protection of a country. It ranges from 1-10 and a higher value denotes a stronger protection	6.267	1.641	The World Competitiveness Yearbook, International Institute for Management Development
WEF-IPR	The degree of IPR protection of a country. It ranges from 1-7 and a higher value denotes a stronger protection	4.826	1.088	Global Competitiveness Report, World Economic Forum (WEF).
G&P-IPR	The degree of IPR protection of a country. It ranges from 0-5 and a higher value denotes a stronger protection	3.993	0.647	Park (2008), *Research Policy*
RD	R&D expenditure (US$ million)	10,047.72	24,880.09	World Development Indicators (WDI), online databank, The World Bank.
RDINT	R&D intensity (ratio of R&D expenditure to GDP)	1.381	0.944	
MANUF	The value added in manufacturing (percent of GDP)	20.629	5.648	
RERD	Researchers in R&D (per million people)	2,260.841	1,879.766	Trade Statistics Databank, Ministry of Economic Affairs, Taiwan
OPEN	Ratio of trade to GDP	85.316	65.780	
PRGDP	Annual real gross domestic product per capita	14,696.44	11,298.38	
POP	The number of population in country (thousand)	99,681.32	255,332.1	
EXP	Country's exports to the U.S (US$ million)	27,924.65	50,863.58	

Note: The means and standard errors are calculated by pooling data for the 1997-2006 periods.

IV. *Empirical Analyses*

1. Panel Regression without Threshold Effects

At first, we treat all countries as the same group and employ the conventional panel regression model to implement the empirical estimation – that is, we assume a linear relation between IPRs and innovation across countries. Using US patents as the dependent variable, the estimating results serve as the benchmark model and can be compared with findings in the previous studies. Table 2 reports the results of two cases of panel regression using IMD and WEF IPRs index, respectively. Based on the significance of Hausman tests, results shown in columns (1) and (2) are obtained using fixed effect (FE) and random effect (RE) models, respectively.

Table 2. Initial Results – Panel Data Model

Variable	(1) IMD-IPR, FE	(2) WEF-IPR, RE
ln*RD*	0.855***	0.969***
	(0.121)	(0.088)
ln*RERD*	0.242**	0.320***
	(0.109)	(0.093)
ln*POP*	2.644***	0.201*
	(0.750)	(0.105)
ln*OPEN*	0.930***	0.838***
	(0.161)	(0.135)
ln*EXP*	-0.005	0.103*
	(0.079)	(0.061)
MANU	-0.015	-0.023**
	(0.011)	(0.010)
ln*IPRP*	0.424***	0.322**
	(0.125)	(0.159)
R-square	0.269	0.888
Hausman test	13.88*	6.67

Note: Figures in parentheses are standard deviations. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

As R&D expenditure is the key input of patent production, it is, of course, associated with a significantly positive coefficient. The estimated R&D elasticity hovers 0.9, which is similar to that obtained using U.S. and OECD countries, hovering between 0.6 and 1.0. It suggests that a 1% increase in R&D expenditure, the number of patent applications increases with about 0.9%. The high elasticity highlights the key role R&D plays on fostering innovation and it matters to both developed and developing countries.

Other country characteristics variables, except for the *MANU* variable, are positively and significantly impacting on patents. The innovation effect of expenditure can act by accompanying with the essential intangible asset of human capital. Thus, it is crucial to invest in excellent R&D personnel. Moreover, the significantly coefficients on openness and export variables reveal that international trade is an important channel for learning knowledge from other countries. This finding supports the claim in Eaton and Kortum (1996) and Yang and Kuo (2008) that international patenting is trade-related. *MANU* variable is not as expected to associate with a positive coefficient. The possible reason is that the industrial structure in advanced countries is generally composed of a small share of manufacturing, while these countries apply more patents, thereby leading to a negative correlation.

Focusing on the main variable we concern, the *IPRP* variable, the estimated coefficients of IMD and WEF IPRs indices, are positive and significant at the 1% statistical level. This result demonstrates that stronger IPRs protection overall induces more innovations when we do not consider the potential threshold effects on the IPRs-innovations nexus. This finding is consistent with previous studies, such as Yang and Maskus (2001), Schneider (2005), and Kim *et al.* (2012). It also lends supportive evidence to developed countries' argument that the enforcement of stronger IPRs protection is helpful to create a favored environment for innovations and induces more innovations in both developed and developing countries.[13]

2. Panel Regression with Threshold Effects

As discussed previously, South and North countries have divergent points on the innovation-enhancing effect brought about by stronger IPRs protection. The widespread argument among developing countries regarding IPRs is that a weak protection is beneficial to technological progress, as it not only avoids tort litigation, but also convenient for firms to copy and imitate foreign advanced technologies. Theoretical literature, e.g., Furukawa (2010) and Gangopadhyay and Mondal (2012), argue also an inverted-U-shaped relationship between IPRs protection and innovation. In other words, stronger IPRs protection turns out to have a negative impact on innovations in developing/ less developed countries, as is their argument. The threshold model provides an appropriate approach to examine the possible divergent effect. In the case of existence of this divergent effect between developing and developed countries, a natural candidate for the threshold variable is GDP per capita. The multiple threshold regression function can be specified as follows:

$$\begin{aligned}\ln PAT_{it} = {} & \beta_0 + \beta_1 \ln RD_{it} + \beta_2 \ln RERD_{it} + \beta_3 \ln OPEN_{it} + \beta_4 \ln POP_{it} \\ & + \beta_5 \ln EXP_{it} + \beta_6 MANU_{it} + \beta_7 \ln IPRP_{it} I(PRGDP \leq \gamma_1) \\ & + \beta_8 \ln IPRP_{it} I(\gamma_1 < PRGDP \leq \gamma_2) + \beta_9 \ln IPRP_{it} I(\gamma_2 < PRGDP) + \varepsilon_{it}\end{aligned} \tag{7}$$

In practice, there are single or multiple thresholds existing in the above patent equation. The first step is identifying the number of thresholds before estimating equation (7). Applying the method developed in Hansen (1999), we test the existence of the possible number of thresholds, including one, two, and three thresholds, and report the test statistics along with their bootstrap p-values in Table 3. The results in table 3 show that the tests for single threshold are significant at the 5% or 1% level, which indicate that the null hypothesis H_0: $\beta_1' = \beta_2'$ is rejected in both cases. Moreover, the tests for double thresholds are far to be statistically significant with a bootstrap p-value of 0.120 and 0.130, respectively. The diagnoses suggest that one threshold exists in terms of per capita GDP in the IPRs-innovations nexus across countries, lending preliminary support to the theoretical prediction that threshold effects are possible.

Once the threshold is identified, we first examine whether the country classification according to this threshold is adequate and meets the practice. According to the calculation obtained by the panel threshold model, the single threshold point appears at US$4,295.92 3of per capita GDP for our sample countries.[14] Separating samples into two groups based on this threshold point, 27 countries are classified into the group of middle-high-income countries, 13 countries belong to the group of middle-low-income countries, and other 2 countries switched middle-and-low-income countries during the sampling period. Table 4 demonstrates the country lists in both groups. It is apparent that countries classified into the high-income country list are nearly consistent with the classification of 'middle high economies' by International Monetary

[13] We have been also collected data for the pre-TRIPs period to conduct empirical estimations. Though the limitation of information availability with regard to R&D and IPRs index enables us to have only 68 observations, empirical results remain a positive relationship between IMD-IPR (G&P IPR index) and innovations. The estimating results are available upon request from the authors.

[14] Falvey *et al*. (2006) examine the IPRs – growth nexus using threshold model and find a high-income threshold for IPRs effect at GDP per capita $10, 928 at the 1995 constant $US.

TABLE 3. TESTS FOR THRESHOLD EFFECTS – GDP PER CAPITA

	Threshold variable—GDP per capita	
	IMD-IPR	WEF-IPR
Test for single threshold		
F_1	35.4	49.2
P-value	0.050	0.010
(10%, 5%, 1% critical value)	(30.7, 32.0, 50.0)	(34.2, 39.8, 47.5)
Test for double threshold		
F_2	28.4	30.5
P-value	0.120	0.130
(10%, 5%, 1% critical value)	(29.0, 31.4, 39.2)	(32.8, 36.2, 45.1)

TABLE 4. GROUPING OF COUNTRIES BASED ON GDP PER CAPITA

Group1 *GDP per capita≦$4295.923*	Group 2 *GDP per capita >$4295.923*	
Brazil	Argentina	Italy
Chile	Australia	Japan
China	Austria	Mexico
Colombia	Belgium	Netherlands
India	Canada	New Zealand
Indonesia	Czech Republic	Norway
Malaysia	Demark	Portugal
Poland	Finland	Singapore
Slovakia	France	South Korea
South Africa	Germany	Spain
Thailand	Hong Kong	Sweden
Turkey	Hungary	Switzerland
Venezuela	Iceland	United Kingdom
	Ireland	

Note: The classification of sample countries is done in the base of year by year, implying that one country may switch from middle-and-low-income countries to middle-and-high- income country, such as Greece and Russia. To save space, we summarize as one table. One country is classified into groups 1 or 2, depending on the frequency of either group it appears more. The year-by-year classification is available upon request.Hong Kong, Greece, Russia

Fund (IMF).[15] It suggests that the divergence for the effects of strengthening IPRs may exist between developing and developed countries, as argued by developing countries.

Based on the above tests, we have identified the threshold point, enabling us to further differentiate the role of IPRs on innovations between developed and developing countries. Table 5 presents estimates obtained from the panel threshold model using IMD and WEF IPRs index, respectively. Both estimates are quite similar that most variables, except *EXP* variable, remain to have a significantly positive influence on fostering innovations.

Turning to the results of *IPRP* variable, the threshold points are the same for cases of using IMD and WEF IPRs indices that per capita GDP equals US$4, 295.923 (PRGDP = $

[15] See IMF's advanced countries list, World Economic Outlook database.

Table 5. Threshold Regression Based on GDP per Capita

IPR Variable	Threshold variable—GDP per capita					
	IMD-IPR			WEF-IPR		
	(1)	(2)	(3)	(1)	(2)	(3)
ln*RD*	0.955***	0.947***		0.971***	0.962***	
	(0.233)	(0.162)		(0.241)	(0.161)	
ln*RERD*	-0.012		0.605***	-0.014		0.597***
	(0.165)		(0.113)	(0.176)		(0.110)
ln*POP*	4.110***	4.083***	3.560***	3.730***	3.699***	4.334***
	(1.128)	(1.132)	(1.229)	(1.089)	(1.099)	(1.200)
ln*OPEN*	0.871***	0.871***	0.815***	0.869***	0.869***	0.953***
	(0.175)	(0.175)	(0.197)	(0.178)	(0.178)	(0.212)
ln*EXP*	-0.079	-0.079	0.106	-0.045	-0.045	0.075
	(0.088)	(0.087)	(0.089)	(0.088)	(0.087)	(0.090)
MANU	-0.012	-0.012	-0.024**	-0.012	-0.012	-0.027**
	(0.010)	(0.010)	(0.012)	(0.011)	(0.011)	(0.012)
ln*IPRP*	0.179	0.180	0.083			
(GDP per capita≦4,295.923)	(0.175)	(0.174)	(0.186)			
ln*IPRP*	0.514***	0.513***	0.674***			
(4,295.923＜GDP per capita)	(0.169)	(0.171)	(0.166)			
ln*IPRP*				-0.045	-0.042	0.256
(GDP per capita≦4,295.923)				(0.207)	(0.200)	(0.209)
ln*IPRP*				0.400**	0.402**	0.739***
(4,295.923＜GDP per capita)				(0.180)	(0.177)	(0.193)

Note: All model estimated using White-corrected standard errors. *** and ** represent statistical significance at the 1% and 5% levels, respectively.

4,295.923). In the middle-high-income group of PRGDP>\$4,295.9, the estimated coefficients of IMD and WEF IPRs indices are positive and significant at the 1% statistical level and have a similar patent-enhancing effect. This result lends the supportive view of pro-patent policy hypothesis proposed in Merges (1992) that pro-patent legislative changes encourage to induce more patents. It is consistent with the consensus among developed countries that all countries should strengthen and harmonize the means for protecting IPRs to establish a stronger IPRs regime.

As for the middle-low-income group of PRGDP ≤ \$4,295.923, the coefficients of *IPRP* in terms of IMD and WEF IPRs indices are statistically insignificant, suggesting no innovation-enhancing effect brought about by strengthening IPRs for lower income countries (developing countries). This outcome contradicts earlier findings in Table 2 obtained by treating all countries as the same group. The results do not find evidence that a stronger IPRs protection will hamper technological progress, as argued by developing countries. Correspondingly, this finding also leads no support to developed countries' claim that strengthening IPRs protection is helpful to foster innovations for developing countries.

The above findings suggest also the advantage of panel threshold model. The positive IPRs-innovation nexus found in Table 2 is because that this positive innovation effect for the large share of developed countries in the sample dominates the insignificant effect for developing countries (the share of country number is relative small). Panel threshold model provides as a more adequate econometric technique to separate the possible difference in the IPRs' effect on innovations across sub-groups. Theoretical literature, such as Furukawa (2010) and Gangopadhyay and Mondal (2012), indicate that the influence of IPRs on innovation may exhibit an inverted-U-shaped relationship. Hudson and Minea (2013) also find the existence of a nonlinearity relationship between IPRs and innovation, depending on the initial levels of both IPRs and per capita GDP. As strengthening of IPRs protection has no significant innovation-enhancing effect for middle-low-income countries, our finding tends to support the aforementioned theoretical claims as well as empirical findings.

Comparing results obtained using conventional and threshold panel data models, two remarkable implications should be emphasized. First, as there is threshold in the IPRs effect being found, it suggests a nonlinear relation in the IPRs – innovation nexus and tends to echo developing countries' claim regarding the effect of strengthening IPRs protection. In terms of econometrics perspective, previous studies using conventional panel data model may suffer biased estimates as parameter heterogeneity among cross-sectional units is found. That is, the elasticity of innovation with respect to IPRs protection varies between various country groups.

Second, when a country belongs to the middle-low-income group, it needs no strong IPRs framework or does not care, then passing to the middle-high-income group the IPRs framework does matter. The possible U-shape behavior predicted by theoretical studies in Chen and Puttitanun (2005) can be witnessed by countries belonging in two types of countries simultaneously. For example, Greece and Russia appeared in earlier period as middle-low-income countries and emerged as middle-high-income countries in later period. Accordingly, their enforcements of IPRs protection evaluated as IMD and WEF IPRs increased gradually. Actually, most middle-low-income countries have also gradually switched their IPRs protection toward a strong regime along with their economic development, such as India. It is consistent with findings in Forero-Pineda (2006) that, in face of international changes in IPRs, science and technology policy-making in developing countries appears a change in the attitude has taken place. However, China is an exception that it experienced a weakened IPRs protection along with its fast economic growth. Therefore, more samples of middle-low-income countries are helpful to examine the existence of double threshold.

V. *Robustness Check*

One may argue that the estimating results are sensitive to the choice of IPRs index, threshold variable, as well as the measure of innovations. Moreover, the problem of time lag between R&D and patent applications is a longstanding issue. To obtain robust results, the section further implements various estimations.

1. Sensibility of IPRs Index

Indeed, the Ginarte-Park IPRs index (hereafter, G&P index) is the most widely adopted one in the previous studies, as it is a more objective measure regarding the degree of IPRs enforcement. This index is designed to range between 0 and 5 by considering five components of the laws: duration of protection, extent of coverage, membership in international patent agreements, provisions for loss of protection, and enforcement measures. A higher value of G&P index denotes a stronger IPRs protection. This study employs the interpolation to calculate the value of G&P IPRs index for the unavailable years and then implements empirical

Table 6. Robustness Check – Using G&P-IPR Index

	(1) RE	(2) threshold
ln*RD*	0.773***	0.662***
	(0.081)	(0.164)
ln*RERD*	0.323***	0.433***
	(0.080)	(0.126)
ln*POP*	0.246**	0.599
	(0.102)	(0.864)
ln*OPEN*	0.414***	0.538***
	(0.126)	(0.151)
ln*EXP*	0.044	-0.012
	(0.055)	(0.080)
MANU	-0.013	-0.016
	(0.008)	(0.010)
G&P-IPRP	2.207***	
	(0.184)	
(GDP per capita≦2,109.952)		2.442***
G&P-IPRP		(0.272)
(2,109.952< GDP per capita)		1.893***
G&P-IPRP		(0.297)
R-square	0.876	
Hausman test	0.26	

Note: All model estimated using White-corrected standard errors. *** and ** represent statistical significance at the 1% and 5% levels, respectively.

estimations of linear panel and panel threshold models. Table 6 illustrates the empirical results.

As demonstrated in column (1), the RE estimates of panel data model are quite similar as results in Table 2 that employ IPRs indices surveyed by IMD and WEF. *G&P IPRP* is positively associated with innovations, but with a larger innovation elasticity. This stronger impact on patenting is attributed to the narrow-scaled G&P index, that ranges between 0 and 5. Thus, a one percent increase in the degree of strengthening IPRs induces a larger percent of patenting then those of IMD (0-10) and WEF (1-7) IPRs indices.

On the other hand, the estimated effect of G&P index obtained from the threshold model (in columns 2) changes substantially. Despite it remains to exhibit a threshold, the calculated threshold value of per capita lowers from US$4,295.9 to US$2,109.9. Crucially, estimates in columns (2) illustrate that all the coefficients of *G&P-IPRP* variables are positive and significant at the 1% statistical level, highlighting a positive relationship between strengthening IPRs and innovations for all countries of various economic development degrees. Developing and less-developed countries generally favor a weak IPRs regime based on the belief that the weak IPRs protection helps them absorb and imitate foreign technologies, leading to a faster technological progress. This widely spread argument is not supported in this study; and alternatively, our findings tend to support developed countries' claim on the extension of international IPRs that it is beneficial for South countries to attract more FDI and technology transfer, contributing to their technological progress in the long run.

TABLE 7. ROBUSTNESS CHECK – USING RD INTENSITY AS THRESHOLD

Variable	Threshold variable—*RD* intensity					
	IMD-IPR			WEF-IPR		
	(1)	(2)	(3)	(1)	(2)	(3)
ln*RD*	1.008***	1.075***		0.992***	1.084***	
	(0.222)	(0.158)		(0.237)	(0.159)	
ln*RERD*	0.098		0.505***	0.132		0.493***
	(0.158)		(0.118)	(0.170)		(0.125)
ln*POP*	3.817***	4.037***	4.224***	3.508***	3.795***	3.843***
	(1.134)	(1.146)	(1.244)	(1.133)	(1.154)	(1.246)
ln*OPEN*	0.874***	0.875***	1.048***	0.915***	0.913***	1.080***
	(0.173)	(0.172)	(0.223)	(0.181)	(0.179)	(0.226)
ln*EXP*	-0.033	-0.036	0.151	-0.009	-0.014	0.209**
	(0.089)	(0.089)	(0.095)	(0.091)	(0.091)	(0.101)
MANU	-0.016	-0.014	-0.030**	-0.019	-0.017	-0.035***
	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.013)
ln*IPRP*	0.512***	0.519***	-0.185			
(RD intensity≦0.644%)	(0.171)	(0.175)	(0.269)			
ln*IPRP*	0.344**	0.348**	0.581***			
(0.644%＜RD intensity)	(0.163)	(0.166)	(0.162)			
ln*IPRP*				0.398**	0.384**	-0.515
(RD intensity≦0.644%)				(0.197)	(0.191)	(0.381)
ln*IPRP*				0.340*	0.323*	0.558***
(0.644%＜RD intensity)				(0.200)	(0.194)	(0.202)

Note: All model estimated using White-corrected standard errors. *** and ** represent statistical significance at the 1% and 5% levels, respectively.

2. Sensibility of Threshold Variable and Time Lag Structure

The possible divergent effect of IPRs protection on innovations may exist in various groups of R&D intensity rather than national degree of economic development, because IPRs protection is more relevant to R&D efforts. We first replace the threshold variable of GDP per capita by R&D intensity (R&D expenditure to GDP ratio) and then re-implement the estimation of panel threshold model.

Again, the tests for threshold effects prove the existence of a single threshold, but the test statistic for double thresholds is not significant at a conventional statistical level. This study therefore reports results obtained from the single threshold model in Table 7.

Compared with results in Table 5, all variables overall execute a similar effect on innovations in terms of patent counts. However, there are some points worth noting. First, the threshold point i cuts in R&D intensity 0.644% no matter the IPRs protection is proxied by either IMD or WEF index. Second and crucially, the estimated coefficients of IPRs protection variable (*IPRP*) are positive and significant at the 1% statistical level for high R&D intensity countries (R&D intensity > 0.644%), in both cases of using IMD and WEF IPRs index. It suggests that strengthening IPRs protection in high R&D intensity countries indeed has a positive relation with innovation. As high R&D intensity countries are generally high-income countries, this result is consistent with previous finding using per capita GDP as the threshold and confirms developed countries' argument regarding the effectiveness of IPRs protection on

Table 8. Robustness Check – Using Two-year Lagged Independent Variable

Variable	Threshold variable—*GDP per capita*	
	IMD-IPR	*WEF-IPR*
ln*RD*	0.467***	0.432**
	(0.160)	(0.183)
ln*RERD*	0.268*	0.327**
	(0.158)	(0.151)
ln*POP*	1.075	2.562**
	(1.026)	(1.099)
ln*OPEN*	0.466**	0.509***
	(0.200)	(0.196)
ln*EXP*	0.039	-0.061
	(0.071)	(0.073)
MANU	-0.006	-0.011
	(0.012)	(0.012)
ln*IPRP*	0.029	
(GDP per capita≦4,295.923)	(0.174)	
ln*IPRP*	0.364**	
(4,295.923＜GDP per capita)	(0.162)	
ln*IPRP*		0.082
(GDP per capita≦4,295.923)		(0.166)
ln*IPRP*		0.498***
(4,295.923＜GDP per capita)		(0.147)

Note: All model estimated using White-corrected standard errors. ***, **, and * represents statistical significance at the 1%, 5%, and 10% level, respectively.

spurring innovations. On the other hand, the *IPRP* variable is also associated with a positive coefficient for low R&D intensity countries (of RD intensity $\leq$ 0.644%), while it is not statistically significant in all estimations. Developing countries claim that a stronger IPRs protection may hamper their technological progress, but this argument is not supported.

To deal with the problem of time lag between inputs and outputs in the knowledge production function as well as endogenous problem of using contemporaneous independent variables, we now replace the current period of R&D expenditure and other variables by lagged two-year variables. Implementing the tests of threshold effects, we find the existence of a single threshold using per capita GDP as the threshold and then report the estimates obtained from panel (single) threshold model in Table 8.

As R&D expenditure and R&D personnel are key inputs of innovations, they remain to have a significantly positive impact on innovations. The influence of IPRs protection on innovation remains similar as those obtained on Table 5. There is a single threshold at US$ 4,295.9 per capita GDP and the positive relationship between IPRs and innovation is witnessed for middle-high-income countries in all estimations, using either IPRs index developed by WES or IMD. In other word, IPRs protection is again proved to act a considerable positive impact on fostering innovations across middle-high-income countries. On the other hand, the coefficient of *IPRP* remains insignificant positive for middle-low-income countries.

3. Sensibility of Innovation Measure

As discussed previously and many studies suggested, the number of US patent applications

TABLE 9. ROBUSTNESS CHECK – USING NUMBER OF PATENT GRANTED AS MEASURE OF INOVATIONS

IPR Variable	Dependent Variable—number of patent granted					
	IMD-IPR			WEF-IPR		
	(1)	(2)	(3)	(1)	(2)	(3)
ln*RD*	0.876***	1.003***		0.884***	1.039***	
	(0.151)	(0.118)		(0.154)	(0.125)	
ln*RERD*	0.190		0.571***	0.226		0.751***
	(0.150)		(0.137)	(0.158)		(0.133)
ln*POP*	2.801***	3.259***	4.084***	2.244**	2.764***	1.922**
	(0.966)	(0.866)	(1.212)	(0.977)	(0.879)	(1.097)
ln*OPEN*	0.330	0.342	0.315	0.329	0.338	0.369
	(0.214)	(0.211)	(0.234)	(0.225)	(0.220)	(0.259)
ln*EXP*	-0.260***	-0.269***	-0.168**	-0.238***	-0.249***	-0.059
	(0.090)	(0.092)	(0.092)	(0.092)	(0.095)	(0.095)
MANU	-0.004	-0.002	-0.012	-0.008	-0.005	-0.018
	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)	(0.018)
ln*IPRP*	-0.074	-0.018	0.201			
(GDP per capita≦4,081.025)	(0.213)	(0.205)	(0.160)			
ln*IPRP*	0.476***	0.490***	0.794***			
(4,081.025＜GDP per capita)	(0.153)	(0.155)	(0.172)			
ln*IPRP*				0.080	0.057	0.298
(GDP per capita≦4,081.025)				(0.224)	(0.226)	(0.237)
ln*IPRP*				0.596**	0.566**	0.468
(4,081.025＜GDP per capita)				(0.304)	(0.295)	(0.329)

Note: All model estimated using White-corrected standard errors. *** and ** represent statistical significance at the 1% and 5% levels, respectively.

is probably not an adequate measure of innovation counts. For robustness check, we adopt also the number of patent granted as the proxy of innovations and then implement estimations of panel threshold model using the per capita GDP as the threshold. Table 9 displays the results.

Compared with estimates in Table 5, the results are overall very similar. As we replace the measure of innovation (patent applications) by patent granted, the estimated threshold changes slightly from US$4, 295.923 to US$4, 081.025, while it does not affect year-by-year country classifications of middle-high-income and middle-low-income countries. Crucially, the findings regarding the impacts of IPRs protection on fostering innovations remain the same. The innovation-enhancing effect of strengthening IPRs is witnessed for only middle-high-income countries. Alternatively, the influence of IPRs protection, in terms of IMD-IPR or WEF-IPR, on innovations is insignificant for middle-low-income countries.[16]

In summary, various robustness checks find the existence of thresholds in the IPRs–innovations nexus relationship in terms of economic development degree or R&D intensity. While various estimates affirm a positive impact brought about by strengthening IPRs protection for developed countries, the innovation-enhancing effect of IPRs protection diverges among various estimates, depending on the use of IPRs measures. As various IPRs indexes (IMD-IPR, WEF-IPR and G&P-IPR) have different scale and they are constructed based on diverse evaluating

[16] We have also conducted robustness check by excluding China and reached similar results. To save space, the results are not shown here, while they are available upon request from the authors.

items, we have no attempt to conclude which measures are better. This study just aims to provide an overall picture with regard to the IPRs – innovation nexus.

In light of the international debate regarding the role of IPRs on innovations between South and North countries, the common argument proposed by South countries that stronger IPRs protection is harmful to their technological progress is less supported. Alternatively, the analyses tends to advocate the perspective of harmonizing the strength of IPRs enforcement across countries indicated by developed countries, as the IPRs is witnessed a significantly positive influence on innovations for non-high-income countries in some specifications. The existence of threshold does prove the different influences of strengthening IPRs protection on innovations between developing and developed countries. The actual relation between IPRs protection and innovation is probably non-monotonically, as d indicated in Chen and Puttitanun (2005), Furukawa (2010), and Gangopadhyay and Mondal (2012).

VI. *Concluding Remarks and Policy Implications*

Ever since the TRIPs was enacted to set the minimum standards of intellectual property rights protection to be provided by each WTO member, how to strengthen and harmonize the means for protecting IPRs has stimulated great attention in the arena of international economic policy in the past decade. Specifically, the divergence for effects of strengthening IPRs on innovations has gradually widened between North and South countries. Does a stronger regime of IPRs protection really induce more innovations? Theoretical works on the relationship between IPRs and innovations offer mixed results, the limited empirical studies focusing on this issue do not consider the possibility of non-linearity in the IPRs–innovations nexus.

This paper empirically examines the role of IPRs protection on stimulating innovations across countries. To consider the possible difference in the relationship between IPRs and innovations in developed and developing countries, this study employs the technique of panel threshold model to differentiate the impact of strengthening IPRs on innovations in various countries groups of economic development degree. Based on a panel dataset of 42 countries over the 1997-2006 period, our empirical results are summarized as follows. First, the estimates obtained by the conventional panel regression model show that overall there is a positive relationship between the strengthening IPRs protection and innovations, which is consistent with previous studies, such as Schneider (2005) and Kim *et al*. (2012). It is probably attributed to the fact that the availability of R&D data concentrates on middle- and high-income countries. Second and most importantly, the threshold tests find that the thresholds do exist, suggesting that the relationship between IPRs and innovations is non-linear, supporting theoretical literature, such as Furukawa (2010) and Gangopadhyay and Mondal (2012). As the panel data model does not consider this non-linearity, it may lead to biased estimates on the impact of IPRs on innovations. Third, strengthening IPRs is beneficial to foster innovations in middle-high-income (developed) countries, while it shows a diverse influence on innovations for developing countries in various estimates. It suggests the need of further studies to clarify the IPRs-innovation nexus for less developed and developing countries by using a larger sample.

Some policy implications are inspired from the results. Given the circumstance that IPRs protection overall exhibits a positive influence on innovations, strengthening and harmonizing the means for protecting IPRs are reasonable and practical from the long-run perspective, as every country can raise their economic development gradually. Second, despite the positive relationship between IPRs protection and innovations for developing countries is not affirmative, but it seems to be less harmful to innovations. If developing countries continue to favor a weak IPRs regime, it will lead to the serious problem of prevailed piracy and imitation in developing countries, causing developed countries to encounter a great economic loss. Indeed, the influences of IPRs on economic activity are multi-dimensional that a stronger IPRs protection is beneficial to economic growth (Falvey *et al*., 2006), FDI, and technology transfer (Smith, 2001) for developing countries. Therefore, non-high-income countries should take other effects brought about by strengthening IPRs into account and then decide an appropriate degree of IPRs protection from a long-run perspective. Finally, on this evidence at least, developing countries joining the WTO should be able to reap the broad benefits of free trade and investments without sacrificing technological progress in order to meet the accompanying TRIPs obligations.

The inconsistent results in estimates for developing countries suggest the need of further studies to improve problems encountered in this study. Searching for a better innovation indicator for international comparison remains as an important issue on the one hand. On the other hand, collecting a larger sample to include more less-developed countries is required, as the degree of the Ginarte-Park index increases to be similar and has a small variation among high-income countries (Park, 2008).

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