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Intellectual Property Rights and Innovation in Developing Countries

Yongmin Chen
Department of Economics, University of Colorado at Boulder
Boulder, Colorado

Thitima Puttitanun
Department of Economics, University of Colorado at Boulder
Boulder, Colorado

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Center for Economic Analysis
Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

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Yongmin Chen

Thitima Puttitanun

Department of Economics, University of Colorado at Boulder

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Abstract. This paper studies the relations between intellectual property rights (IPRs) and innovation in developing countries. While weak IPRs facilitate the imitation of foreign technologies, stronger IPRs encourage domestic innovative activities. A model is developed to illustrate how this trade off may affect a developing country's choice of IPRs. It is shown that innovations in a developing country increase in its IPRs, and a country's IPRs can depend on its level of development in a non-monotonic way, first decreasing and then increasing. We evaluate these theoretical results empirically, using a panel data set including 64 developing countries over the 1975-1995 period. The empirical evidence confirms the positive impact of IPRs on innovations in developing countries, and suggests the presence of a U-shaped relationship between IPRs and economic development.

Keywords: Intellectual property rights; Innovation; Economic development

JEL classification: O34; O1.

Contact: Yongmin Chen, Department of Economics, University of Colorado at Boulder, Boulder, CO, 80309. Phone: (303)492-8736; e-mail: Yongmin.chen@colorado.edu.

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1. INTRODUCTION

The protection of intellectual property rights in developing countries has been a much debated issue in recent years. This debate is often placed in a North-South framework, where the predominant view is that southern developing countries tend to lose from protecting intellectual property rights (IPRs). The static and partial equilibrium reason for this loss is that IPRs protection will strengthen the market power of northern innovating firms and raise prices in developing countries (Chin and Grossman, 1988; Deardorff, 1992).[1] But even dynamic and general equilibrium factors are accounted for, the South need not fare better from tight IPRs, partly due to the adverse terms-of-trade effect and the possible slowing down of northern innovations over time (Helpman, 1993). In fact, Helpman concludes:

"Who benefits from tight intellectual property rights in less developed countries? My analysis suggests that if anyone benefits, it is not the South." (Helpman, 1993, pp. 1274).

There are, however, several arguments of why developing countries need to increase their protections of IPRs. First, as Diwan and Rodrik (1991) argue, northern and southern countries generally have different technology needs and, without the southern protection of IPRs, northern countries would not develop technologies largely needed by the South. Second, northern firms may react to the lack of IPRs in the South by making their technologies more difficult to imitate, which can result in less efficient research technologies and less northern innovations (Taylor, 1993, 1994; Yang and Maskus, 2001). Third, even if greater protection of IPRs does not directly benefit the South, it could still increase world welfare; therefore, there are gains from international cooperations that tighten IPRs in developing countries. In fact, issues on trade-related intellectual property rights (TRIPS) have been a key element in the

[1] According to Primo Braga et al (2000), this view actually existed much earlier; in1970s, it was widely accepted among policymakers that developing countries had a limited ability to create much intellectual property and thus little to gain from IPRs protection to the extent that they would be mainly granting monopolies to foreign patentees.

WTO negotiations, and the strengthening of IPRs has been raised as a condition for many developing countries' entry to the WTO (Maskus, 2000). Importantly, even these arguments for tight southern IPRs seem to suggest that, if not for strategic reactions or pressures from the North, the southern developing countries would have little incentive to protect IPRs.

The purpose of this paper is to offer an alternative perspective on the protection of IPRs in developing countries. We shall argue that even if strategic behavior of or pressures from the North is not a concern, a developing country may still want to protect IPRs, for domestic economic considerations. In particular, there may be domestic innovative activities that would rise under stronger IPRs. For such an economy, there could be an optimal level of IPRs, which balances the trade-off between facilitating the imitation of northern advanced technologies and providing incentives for domestic innovations. To motivate this approach, we note that while most innovations originate from the North, there are substantial innovative activities in many developing countries, as measured by patent applications filed in these countries by domestic inventors.[2] For instance, during 1985-95, the number of such applications was 2757 in Brazil, 1545 in India, 5549 in South Africa, and 59249 in South Korea; as compared to 9325 in Australia, 3039 in Canada, 335061 in Japan, and 127476 in the US during the same period. Furthermore, although collectively IPRs in the South can significantly affect northern innovation incentives, the effect of a single developing country may be negligible, as has been noticed by Yang (1998); and such a country may take the northern innovations as determined exogenously.

We consider a simple model of a (small) developing country that has two sectors, an importing sector and a local sector. The importing sector consists of a (northern) foreign firm and a domestic firm. The foreign firm has a patented technology that

[2] The innovative activities we have in mind are much broader than those that can be protected through patents. In fact, activities such as developing a new product that may be granted a trademark or a copyright could be very important for a developing country. The advantage of focusing on patent applications is that there are available data about them, which is important for our empirical analysis.

allows it to produce a product of a higher quality than that can be produced by the domestic firm. However, the domestic firm can raise its product quality by imitating the northern technology, and its ability to do so depends on the tightness of IPRs in this country. The local sector consists of two domestic firms, one of which has the ability to develop a patentable new technology that improves the product quality, while the other local firm can imitate the new technology. Increased protection of IPRs makes imitation in both sectors more difficult, but it has different effects on the country's welfare. In the importing sector, less imitation means lower product quality of the domestic firm and thus less competition for and higher price of the foreign firm. As a result, there is a reduction of consumer surplus and (domestic) social surplus. In the local sector, less imitation means more incentive for the domestic innovating firm to invest in a higher-quality technology (product), which leads to more efficient investment and to a higher social surplus. In a game where the government first chooses the level of IPRs, followed by investment of the domestic innovating firm and then by production in both sectors, we show that the optimal protection of IPRs balances this basic trade-off. In equilibrium, the incentive to innovate by the domestic firm increases in the tightness of IPRs. Furthermore, there exist plausible situations where, starting from a low level of development, increases in the level of development lowers IPRs initially but raises IPRs after a certain point. That is, a developing country's preferred levels of IPRs can exhibit a U-shaped curve with respect to its levels of economic development, given the advanced technologies of the North.

Although our model is highly stylized, we believe that the insights we try to illustrate are very general. We shall later discuss some of the possible extensions of the model, such as allowing foreign innovations to be endogenous, allowing different types of innovations, and allowing more general market conditions. But our basic idea and our main departure from the existing literature remains to emphasize that even without strategic actions or pressures from the North, there can be incentives for a developing country to protect IPRs, and these incentives tend to differ for different countries in the South. It should be emphsized that we are not the first to notice the relations between IPRs and the levels of economic development. In fact, the existence of an empirical U-shaped curve between IPRs and per capita GNP have been nocited by Maskus (2000) and by Primo Braga et al (2000). However, to the best of our knowledge, ours is the first formal model that provides a theoretical explanation for such an empirical relationship: starting from low levels of economic development, an initial increase in a country's technological ability has a greater impact on the efficiency of imitating northern technologies than on the efficiency of domestic innovations, which makes it more desirable for the country to lower IPRs. Once the country's technological ability is above a certain level, the imitation effect starts to be dominated by the innovation effect, and the optimal IPRs tend to increase with the levels of development.

While it is important to recognize in theory that IPRs can be important for developing countries in encouraging domestic innovations and that the incentives to protect IPRs may differ across developing countries, it is interesting to know whether the theoretical possibilities suggested by our model are supported by empirical evidence. A second contribution of this paper is to conduct such an empirical study, using a panel data gathered from various sources that provide measures of IPRs and innovative activities, as well as other variables, in developing countries. Our empirical analysis departs from the literature in several aspects. First, while there have been other empirical studies on the relations between IPRs and innovations/growth, such as Deolalikar and Roller(1989), Gould and Gruben(1997), Lach(1995), Park and Ginarte(1997), Thompson and Rushing(1996,1999), Maskus and McDaniel(1999) and Crosby(2000), they have mostly focused on developed countries or pooled data on both developed and developing countries. Our analysis provides new evidence on developing countries. Second, most existing studies have taken IPRs as exogenously given. As our theoretical analysis shows, a rational developing country may choose an optimal level of IPRs, depending on its economic conditions. We thus treat IPRs endogenously in our empirical analysis. Consistent with our theory predictions, we find that innovations in developing countries are indeed positively and significantly impacted by IPRs, and the levels of IPRs exhibit a U-shaped relation with per capita GDP.

The rest of the paper is organized as follows. Section 2 illustrates our main idea through a simple model and derives our theoretical implications. Section 3 conducts the empirical analysis. Concluding remarks are contained in Section 4.

2. A MODEL OF OPTIMAL IPRS

A developing country can choose its protection for IPRs, $\beta \in [0,1]$, where a higher β indicates tighter protection, with $\beta = 0$ indicating no protection and $\beta = 1$ indicating perfect protection. To parameterize the model, let $\theta \in (0,1]$ be a measure of the country's level of development or technological ability, with a higher θ indicating a higher development level. The country has two sectors, the importing and the local sector.[3] We shall call them A and B, respectively. In sector A, a (northern) foreign firm, denoted by F, sells a product of quality u^F under certain patented technology. A domestic firm, D, may also engage in the production in A, whose product quality is $u^D(\beta;\theta) = u_0 + u^F\phi(\theta)[1-\alpha(\beta)]$, where, $\forall\theta$, $0 \leq \phi(\theta) \leq 1$, $\phi'(\theta) > 0$, $\alpha(\beta) \geq 0$, $\alpha'(\beta) > 0$, $\alpha(1) = 1$, and $0 \leq u_0 \leq u^F(1-\phi(1))$. Thus, the imitation ability of D, measured by $\phi(\theta)$, is higher if θ is higher; D cannot imitate $F's$ technology if there is perfect protection for IPRs; and $D's$ quality improvement from imitation is higher when protection for IPRs is lower. Moreover, even with no IPRs protection, D may not be able to achieve the same technological level as F. There is a continuum of consumers of measure 1 in A. Each consumer in A assigns a value to one unit of the product that is equal to its quality, but has zero valuation for any additional unit.

[3] We assume that the same β applies to both sectors. That is, a government cannot selectively enforce IPRs protection. What we have in mind is a situation where if the government does not protect IPRs in one sector, it will also have difficulty protecting IPRs in another sector, perhaps because government policies change people's expectations about what are acceptable social behaviors.. Our result will be essentially the same if we extend our model to situations where there can be different $\beta's$ in different sectors, as long as these $\beta's$ are positively correlated.

All firms in A have constant unit cost $c^A \in [0, u_0]$.

Sector B also has two firms, L and M, both of which are domestic firms. Firm $L's$ product has quality $v(z;\theta)$, where $z \geq 0$ is L's investment in quality improvement, and $\forall\ \theta,\ v_z(z;\theta) > 0,\ v_z(\infty, \theta) = 0,\ v_{zz}(z, \theta) < 0,\ v_{\theta}(z;\theta) > 0$, and $v_{z\theta}(z;\theta) > 0$. Firm M can also produce in B, with product quality $v^M(\beta;\theta) = v(z;\theta) - \gamma(\beta)(v(z;\theta) - v_0)$, where, $\forall\theta,\ 0 \leq v_0,\ \gamma(0) > \frac{1}{v_z(0,\theta)},\ \gamma'(\beta) > 0$, and $\gamma(1) = 1$. Without further loss of generality, we let $v_0 \equiv 0$ and thus $v^M(\beta;\theta) = v(z;\theta)(1 - \gamma(\beta))$. There is a continuum of consumers of measure $N > 0$ in sector B. Each consumer in B assigns a value to one unit of the product that is equal to its quality, but has zero valuation for any additional unit. All firms in B have constant unit cost $c^B \equiv 0$.

The game is as follows: The government first chooses β, the level of IPRs protection. Firm L then chooses z, its expenditures on R&D. The product qualities of all firms are then determined. The game then moves to the price-competition stage, where firms F and D simultaneously choose prices for their products in market A and firms L and M simultaneously choose prices for their products in market B. Afterwards, possible purchases are made by consumers and production is carried out.

We solve the subgame perfect equilibrium of the game through the usual method of backward induction. Given any β and any $z > 0$, there is a unique Nash equilibrium in each sector at the price-competition stage where the equilibrium prices of firms F, D, L, and M are, respectively:

$$p^F = c^A - u_0 + u^F [1 - \phi(\theta)[1 - \alpha(\beta)]], \qquad p_D^* = c^A; \tag{1}$$

$$p^L = c^B + \gamma(\beta;\theta) v(z;\theta), \qquad p^M = c^B, \tag{2}$$

and all consumers purchase from F in A and purchase from L in B.

We next determine the equilibrium choice of z by L, $z(\beta;\theta)$. Notice that the profit of L is

$$\pi^L = N\left[\left(c^B + \gamma(\beta) v(z;\theta)\right) - c^B\right] - z = N\gamma(\beta) v(z;\theta) - z.$$

The optimal $z(\beta;\theta)$ thus satisfies

$$N\gamma(\beta)\, v_z(z(\beta;\theta);\theta) \le 1, \text{ where the equality holds if } z(\beta;\theta) > 0. \tag{3}$$

Since $\gamma(0) > \frac{1}{v_z(0;\theta)}$ by assumption, we have $\gamma(0)\, v_z(0;\theta) > 1$. Hence $z(\beta;\theta) > 0$ and condition (3) holds in equality. Since $v_{zz}(z;\theta) < 0$ and $v_z(\infty;\theta) = 0$, $z(\beta;\theta)$ exists uniquely.

By the implicit differentiation rule,

$$z_{\beta}(\beta;\theta) = -\frac{\gamma'(\beta)\, v_z(z(\beta;\theta);\theta)}{\gamma(\beta)\, v_{zz}(z(\beta;\theta);\theta)} > 0.$$

$$z_{\theta}(\beta;\theta) = -\frac{v_{z\theta}(z(\beta;\theta);\theta)}{v_{zz}(z(\beta;\theta);\theta)} > 0.$$

We have thus shown:

Proposition 1 *Given any* $\beta \in [0,1]$, $z(\beta;\theta)$ *uniquely solves*

$$N\gamma(\beta;\theta)\, v_z(z(\beta;\theta);\theta) = 1. \tag{4}$$

Furthermore, $z(\beta;\theta) > 0$, $z_{\beta}(\beta;\theta) > 0$, *and* $z_{\theta}(\beta;\theta) > 0$.

Thus, how L would invest in cost reduction depends both on its efficiency in quality improvement (θ) and on the competitor's ability to imitate, the latter of which depends on β. In particular, a higher β results in L's choosing a higher z.

The government's objective is assumed to choose β that maximizes (domestic) social surplus:

$$\begin{aligned} W(\beta) &= u^F - \left(c^A - u_0 + u^F[1-\phi(\theta)[1-\alpha(\beta)]]\right) + N\left(v(z(\beta;\theta);\theta) - c^B\right) - z(\beta;\theta) \\ &= u^F\phi(\theta)[1-\alpha(\beta)] - c^A + u_0 + Nv(z(\beta;\theta);\theta) - z(\beta;\theta), \end{aligned}$$

subject to the constraint that $0 \le \beta \le 1$ (Recall that $c^B = 0$ by assumption).

For any given θ, let the optimal choice of β be $\beta(\theta)$. We have:

Proposition 2 *(i) The optimal $\beta(\theta)$ satisfies*

$$-u^F \phi(\theta)\,\alpha'(\beta(\theta)) + [Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta}(\beta(\theta);\theta) \begin{cases} \leq 0 & if \quad \beta(\theta) < 1 \\ \geq 0 & if \quad \beta(\theta) > 0 \end{cases}, \tag{5}$$

where

$$0 < \beta(\theta) < 1 \text{ } if \text{ } u^F \phi(\theta)\,\alpha'(\beta(\theta)) = [Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta}(\beta(\theta);\theta).$$

(ii) Suppose that $\beta(\theta)$ is unique and $0 < \beta(\theta) < 1$. Then,

$$\beta'(\theta) \begin{cases} > 0 & if \quad u^F \phi'(\theta)\,\alpha'(\beta(\theta)) < [Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta\theta}(\beta(\theta);\theta) \\ < 0 & if \quad u^F \phi'(\theta)\,\alpha'(\beta(\theta)) > [Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta\theta}(\beta(\theta);\theta) \end{cases}. \tag{6}$$

Proof. The result in (i) follows directly from the Kuhn-Tucker first-order condition. To show (ii), we notice that

$$\frac{\partial\left([Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta}(\beta(\theta);\theta) - u^F \phi(\theta)\,\alpha'(\beta(\theta))\right)}{\partial\beta} < 0$$

because $\beta(\theta)$ maximizes $W(\beta)$. Therefore, $\beta'(\theta)$ has the same sign as

$$\begin{aligned} & \frac{\partial\left([Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta}(\beta(\theta);\theta) - u^F \phi(\theta)\,\alpha'(\beta(\theta))\right)}{\partial\theta} \\ = \; & [Nv_z(z(\beta(\theta);\theta);\theta) - 1]\, z_{\beta\theta}(\beta(\theta);\theta) - u^F \phi'(\theta)\,\alpha'(\beta(\theta)). \end{aligned}$$

The conclusion in (6) then follows. ■

An increase in β affects W through the two terms on the left side of (5). The first term represents the reduction in consumer surplus in A. A higher β makes it more difficult for a domestic firm to imitate the more advanced foreign firm's technology, reducing the competition for and raising the equilibrium price of the foreign firm. This effect reduces W. The second term represents the net benefit from quality improvement by firm L in B, which is welfare improving. The choice of $\beta(\theta)$ balances this trade off.

To see how $\beta(\theta)$ will behave, we can consider $u^F\phi'(\theta)\,\alpha'(\beta(\theta))$ as the imitation effect of increasing θ. A higher θ makes an increase in β more costly in sector A, since the potential benefit of imitation in A is higher. On the other hand,

$$[Nv_z(z(\beta(\theta);\theta);\theta)-1]\,z_{\beta\theta}(\beta(\theta);\theta)$$

measures the innovation effect of increasing θ in Sector B. A higher θ increases $v_z(z(\beta(\theta);\theta);\theta)$ and $z_\beta(\beta(\theta);\theta)$, which makes it more desirable to increase β. Starting from low levels of θ, an increase in θ is likely to have a greater impact on the benefits from imitating foreign technologies than the benefits from increasing domestic innovations, and it is thus likely that the imitation effect dominates the innovation effect (Recall that $v_{z\theta}(z;\theta)>0$). When θ is above certain level, the efficiency of domestic innovation can be high enough such that the innovation effect dominates. It is thus possible that $\beta(\theta)$ first decreases and then increases, as can be seen from the following example:

Example. Assume $\alpha(\beta)=1+\ln\left(\frac{1+\beta}{2}\right)$, $\gamma(\beta)=\frac{1+\beta}{2}$, $u^F=1$, $u_0=0$, $\phi(\theta)=\frac{1}{3}(1+2\theta)$, $v(z;\theta)=2\frac{ln(1+z)}{1-\theta}$, $N=1$, and $\theta\in(0,\frac{4}{5}]$. All of our assumptions are satisfied. We have:

$$v_z(z;\theta)=2\frac{1}{1-\theta}\frac{1}{1+z},$$

$$\alpha'(\beta)=\frac{1}{1+\beta}.$$

From

$$\gamma(\beta)\,v_z(z(\beta);\theta)=1,$$

we obtain

$$z(\beta;\theta)=\frac{\beta+\theta}{1-\theta},$$

and

$$z_\beta(\beta;\theta)=\frac{1}{1-\theta}.$$

From

$$u^F \phi(\theta) \alpha'(\beta^*) = [N v_z(z(\beta^*;\theta);\theta) - 1] z_\beta(\beta^*;\theta),$$

we have

$$\frac{1}{3}(1+2\theta)\frac{1}{1+\beta} = \left(2\frac{1}{1-\theta}\frac{1}{1+\frac{\beta+\theta}{1-\theta}} - 1\right)\frac{1}{1-\theta}$$

and thus

$$\beta(\theta) = \frac{2}{3}\theta^2 - \frac{1}{3}\theta + \frac{2}{3}.$$

The $\beta(\theta)$ is U-shaped here, decreasing for $\theta < \frac{1}{4}$ and increasing for $\theta > \frac{1}{4}$. Figure 1 shows the curve of $\beta(\theta)$ from this example. We thus have:

Remark 1 *Under certain parameter values, there exists some $\theta_1 \in (0,1)$ such that $\beta'(\theta) < 0$ if $\theta < \theta_1$ and $\beta'(\theta) > 0$ if $\theta > \theta_1$.*

Figure 1 : relationship between $\beta(\theta)$ and θ

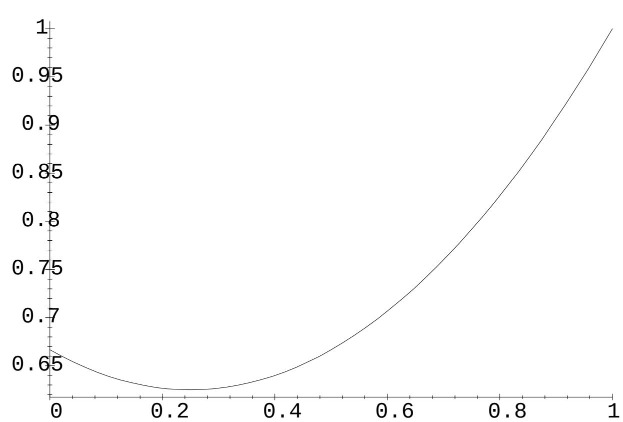

FIG. 1.

In constructing our theoretical model, we have placed great emphasis on making the model transparent and on sharpening the trade-off that is the main interest of our analysis. We can extend the model in many directions without altering the insights of our analysis. For instance, our results would not change if there are more than one imitating domestic firm in sector A and/or in sector B, or if there are several local sectors. If the innovations are about cost reductions (i.e. process innovations instead of product innovations) and the foreign firm has a better technology that gives it a cost advantage in the importing sector, our results would essentially be the same. The outcome that in equilibrium consumers purchase only from one firm in each sector is more of an artifact of our model; but it makes the calculations of (domestic) social surplus more straightforward, and it should be noted that there is effective competition in each sector from the presence of another firm.

Our analysis would essentially be the same if sector A has more general demand functions instead of the unit demand; but having more general demand functions in sector B would complicate the analysis somewhat, since a higher β will then have the usual effect of encouraging innovation but reducing static efficiency (higher deadweight loss after product quality is determined) in B. However, the basic trade-off between increasing the foreign firm's market power and increasing the domestic firm's innovation incentives would remain the same if more general demand functions are introduced in B. The advantage of assuming unit demand is that higher β would always unambiguously increase social surplus in B, allowing us to sharpen the basic trade-off that is the focus of our analysis. Similarly, we could allow the foreign firm's quality advantage to be endogenous, depending on its R&D expenditures, which could further depend on the level of β. This would increase the net benefits of increasing β and lead to a higher equilibrium β, but otherwise our analysis would not be changed.[4] By assuming that the foreign quality advantage is given, we are again focusing on the trade-off that is the main interest of the paper, and it also has a realistic flavor

[4] Zigic(1998) considers an interesting model where the North invests in R&D that has spillovers in a developing country, depending on the level of IPRs, and shows that there can be a range of common interests between the North and South in increasing IPRs protection in the South. Zigic (2000) further allows the South's choice of IPRs to be endogenous, in a North-South trade model.

for a small developing country.

Our theoretical model yields two testable implications:

1. Domestic innovations in a country increase in its protection of IPRs (i.e., $z_{\beta}(\beta;\theta) > 0$) and in its level of development (i.e., $z_{\theta}(\beta;\theta) > 0$).[5]

2. It is possible that a country's level of IPRs first decreases and then increases in its level of development.

We next study the empirical evidence on these two implications.

3. EMPIRICAL ANALYSIS

In this section, we first describe the data to be used for our empirical analysis. We then discuss our econometric model. Results of the econometric analysis are presented at the end of the section.

3.1 Data

The data used in this paper are collected from various sources. Most of the data are collected from the World Development Statistics CD-ROM and Statistical Yearbook by UNESCO. Patent data are collected from the Industrial Property Statistics.

To measure IPRs (β), we use the GP index, a commonly-used measurement of intellectual property rights protection developed by Juan C. Ginarte and Walter G. Park (1997). They examined the patent laws of a comprehensive number of countries, 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. The index scale ranges from 0 to 5, with higher numbers reflecting stronger levels of protection. Since it is a quinquennially index, we have collected the other variables in this study in every 5 years for the 1975-1995 period.

[5] More accurately, our theory says that expenditures on R&D increase in β and θ. But since innovations are deterministic in our model, more R&D implies more quality improvements.

Due to the limited data access, 64 developing countries are included in the sample and 16 out of which are considered Middle-Income countries. Table A1 in the appendix lists the names of these 64 countries.

There are two widely used measures of innovation. The first one is R&D expenditures, which measure the input of innovation. The second is the number of patent applications, which measures inventive output. Since data on R&D expenditures are not available for most developing countries, we use the number of patent applications filed by residents as our measure of innovations by domestic firms (z), denoted by IN.

To measure the level of technological ability or development (θ), we use per capita GDP, denoted by GDPCAP. The data on per capita GDP are obtained from World Development Statistics CD-ROM, in terms of 1995 US dollars.

Table 1

Descriptive Statistics

Variable	**# of Observations**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
IN	290	607.98	4192.13	0	59249
IPRs	306	2.32	0.68	0.33	3.94
GDPCAP	306	2682.51	2622.50	56.50	24128.29
EDU	272	10.97	9.91	0.3	52
TRADE	306	67.51	54.42	9.07	439.03
POP	306	3.55e+07	1.01e+08	344000	9.29e+08
EF	306	4.43	1.51	0.8	9.3

We have also obtained data on several other variables that may affect innovations and/or IPRs. We have data on measures of economic freedom, denoted as EF, from the Economic Freedom of the World 1997, Annual Report (Gwartney and Robert, 1997). The freedom index ranges from 0 to 10, with a higher index indicating a higher level of economic freedom. We use the school gross enrollment ratios at a tertiary level as the basis for an education index, EDU. They are collected from various issues of Statistical Yearbook by UNESCO. We also have data on the population of a country, POP, which is used to measure the size effect. International trade as a percentage of GDP is denoted as TRADE and is used as a measure of trade openness of a country.

The descriptive statistics for the final data set is shown in Table 1.

3.2 Model Specification

The empirical model is a system of two simultaneous equations, one for the intellectual property rights protection and another one for the domestic innovation. Each equation uses a different econometric treatment and will be explained next. The system can be expressed as:

$$IPRs = f(GDPCAP, GDPCAPSQ, EDU, TRADE, EF, WTO) \quad \text{(i)}$$

$$IN = f(IPRs, GDPCAP, EDU, EF, POP) \quad \text{(ii)}$$

where, in addition to the variables explained earlier, we have included GDPCAPSQ, the square of GDPCAP; and WTO, the dummy variable for WTO membership.

Since the data used in this section is a panel of countries over the period 1975-1995, it is expected that there is a country specific effect (unobserved heterogeneity). Therefore, either a fixed-effect model or a random-effect model should be used to take into account the country specific effect.

For equation (i), the first two variables, GDPCAP and GDPCAPSQ, correspond to θ and θ^2 in our theoretical model. Since our theory predicts the possibility of $\beta(\theta)$ having a U shape, we are interested in knowing whether the signs of GDPCAP and GDPCAPSQ will be negative and positive, respectively, as a U-shaped $\beta(\theta)$ curve would suggest. The sign of EF is expected to be positive, since part of this index represents protection of private property. For TRADE, there can be arguments both for a positive sign and for a negative sign. The more open to trade a country is, one may argue, the more it will be influenced to have a higher IPRs. On the other hand, more TRADE could imply that a country is more exposed to advanced foreign technology, and thus domestic firms can benefit more from imitation, suggesting lower IPRs. The sign of WTO dummy variable is expected to be positive since TRIPS[6] require WTO members to increase their IPRs standards. The sign of EDU could be positive, if we believe that a more educated society will respect more for knowledge and thus for IPRs. A Hausman test for random effect supports the fixed-effect model for equation (i) at 5% level of significance.

For equation (ii), the dependent variable, IN, is a count variable involving non-negative integers. Therefore, either a fixed-effect count model or a random-effect count model should be used. The Hausman tests support the fixed-effect model at 5% level of significance. To take into account the count dependent variables, we follow the approach of Hausman, Hall, and Griliches(1984). They specified a Poisson regression to model the probability that the number of patent applications will occur n times (with n = 0,1,2,...):

$$Prob(y_i|x_i) = \frac{\exp(-\mu_i)\mu_i^{y_i}}{y_i!},$$

with y_i being the count of patent applications for the observation i. To incorporate exogenous variables, μ_i can be made a function of the covariates:

$$\mu_i = \exp(\sum k_j x_{ji})$$

where the k's are the coefficients, x's are the covariates (with x_1 set to one), j indicates the j^{th} variable, and i is the observation. The exponential function ensures non-negativity.

However, the Poisson distribution contains the strong assumption that the mean and variance are equal to μ. Therefore the Poisson regression model rarely fits in practice since in most applications the conditional variance is greater than the conditional mean. One way to address the problem is to allow the conditional variance of y to exceed the conditional mean. Then the Poisson regression model reduces to

[6] Trade Related Intellectual Property Rights (TRIPS) is a proposal on IPRs under the General Agreement on Tariffs and Trade (GATT) in the Uruguay Round of Multilateral Trade Negotiations.

the negative binomial model. In the negative binomial regression model, mean μ is replaced with the random variable $\widetilde{\mu}$:

$$\widetilde{\mu}_i = \exp\left(\sum k_j x_{ji} + \varepsilon_i\right).$$

Then $\widetilde{\mu}_i$ is no longer determined but is itself a random variable. As ε_i is unobserved, it is integrated out of the expression by specifying a gamma distribution for the error term[7].

From our theory, the expected sign for IN is positive(i.e., $z_{\beta}(\beta;\theta) > 0)$), and so is for GDPCAP (i.e., $z_{\theta}(\beta;\theta) > 0)$). We also expect the sign of POP to be positive, for the simple reason of a scale effect on innovative activities. The signs for EF and EDU could also be positive, since more economic freedom and more education are likely to encourage innovative activities.

3.3 Statistical Results

The econometric model in this paper is basically a triangular simultaneous equation system. Equation (i) can be estimated with the usual fixed-effect model as mentioned earlier. However, for equation (ii), since the endogenous variable from equation (i), IPRs, also shows up as a right hand side variable, one concern is that it might be correlated to the error term in equation (ii), which will make the coefficients in equation (ii) inconsistent. Therefore, the estimation approach used in equation (ii) is to first obtain the predicted value of IPRs and then use it along with other exogenous variables in the fixed-effect negative binomial regression model. We report the results of first equation regression (fixed effect model) in Table 2 and estimates of equation (ii) (fixed-effect negative binomial regression model[8]) in Table 3. All variables are in log except IN and WTO; standard errors of coefficients are listed in parentheses.

[7] For more detailed explanation about the negative binomial regression model, see Long(1997).

[8] For equation (2), the test for overdispersion shows that overdispersion is present in the dataset. Therefore, the negative binomial regression model is more appropriate than the Poisson regression model.

Table 2 : IPRs Regression

(IPRs as dependent variable)

Variables	**Fixed Effect Model**
Intercept	2.271* (0.720)
GDPCAP	-0.502* (0.186)
GDPCAPSQ	0.033* (0.013)
EDU	0.031 (0.026)
EF	0.177* (0.047)
TRADE	0.018 (0.041)
WTO	0.008 (0.036)
n	272

Estimated coefficients are shown together with the standard errors in parentheses. * denotes 5% level of significance.

From Table 2, GDPCAP and GDPCAPSQ have the signs that confirm the U-shaped relationship between GDPCAP and IPRs. This suggests that countries tend to weaken their patent laws as GDPCAP begin to rise and then strengthen them after a certain point[9]. Based on the results, the curve reaches its minimum at log(GDP per capita) = 7.606, which translates into a per capita GDP of \$2010.22 in 1995 value. This GDP per capita level is well below the GDPCAP mean in our data set, suggesting that for many developing countries increases in GDP per capita increase IPRs. Similar to the findings in Ginarte and Park(1997) and Maskus(2000), the

[9] Maskus(2000) was the first to notice a U-shaped relationship between per capita GNP and IPRs, in a pooled data including both developing and developed countries.

results here suggest that market freedom increases a country's protection of IPRs, and that the EDU and TRADE variables have positive signs but are insignificant. The WTO variable is insignificant even though it has the positive sign. This could be due to the fact that our data started in 1975, far before the enforcement of TRIPS.

Table 3 : Patent Count Regression

Variables	**Fixed Effect Model**
Intercept	-9.455*
	(3.126)
IPRs	4.998*
	(2.380)
GDPCAP	0.541*
	(0.185)
EDU	-0.130
	(0.187)
EF	-0.681
	(0.511)
POP	0.208
	(0.135)
n	167
Log-Likelihood	-534.328

Estimated coefficients are shown together with the standard errors in parentheses. * denotes 5% level of significance.

Table 3 reports the impacts of various variables on domestic innovation, measured by resident patent applications. Both the levels of IPRs and of development (GDPCAP) have positive and significant impact on domestic innovation, but EDU and EF have no detectable impact on resident patent applications. The effect of POP is positive, although it is significant only at 12% level of significance.

Figure 2

Semiparametric estimates of the effect of GDP per capita on IPRs

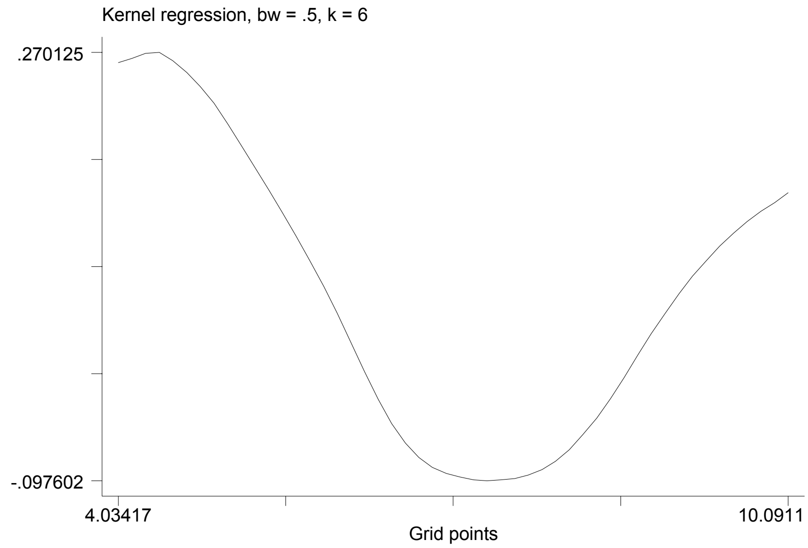

FIG. 2.

Since a key finding here is the U-shaped relationship between IPRs and GDP per capita, we are interested in how robust this result is. An alternative approach is to perform a nonparametric regression estimation, in which the data is given flexibility to characterize its own shape of curvature. This flexible approach can provide remarkably accurate estimates when the underlying regression function is quite nonlinear[10]. While we are interested in the possible relations between IPRs and GDP per capita, IPRs also depend on other variables, as can be seen from table 2. It is therefore desirable to separate the effects of these other variables. However, there is a computational problem to include many variables in a nonparametric regression. One way to combat this problem is to use semiparametric analysis, in which we remain nonparametric about the key variable of interest (GDP per caita), but take

[10]See Lee(1996) and DiNardo and Tobias(2001) for details on Nonparametric Regression Estimation.

a parametric stance about other variables[11]. Using the Guassian kernel function, a semiparametric estimate of the effect of GDP per capita on IPRs, controlling for other variables, is shown in Figure 2. As we can see from Figure 2, this relationship between GDP per capita and IPRs indeed appears to be U-shaped.

The empirical results support the implications of our theoretical model: $z_{\beta}(\beta;\theta) > 0$, $z_{\theta}(\beta;\theta) > 0$; and $\beta(\theta)$ is U-shaped, suggesting that the imitation effect indeed dominates when θ is relatively low but is dominated by the innovation effect when θ is above a certain level. This critical level corresponds to a per capita GDP of about $2010.

4. CONCLUSION

This paper has conducted a theoretical and empirical analysis of intellectual property rights and innovation in developing countries. While lower IPRs facilitate imitations of foreign technologies, which reduces the market power of foreign firms and benefits domestic consumers, a developing country may also need to strengthen IPRs in order to encourage innovations by domestic firms. We show that innovations in a developing country increase in its protection of IPRs, and it is possible that a country's optimal IPRs depend on its level of development (technological ability) in a non-monotonic way, first decreasing and then increasing. We evaluate these theoretical results empirically, using a panel data set including 64 developing countries over the 1975-1995 period. The empirical evidence confirms the positive impact of IPRs on innovations in developing countries, and suggests the presence of a U-shaped relationship between IPRs and levels of economic development.

The conventional wisdom on IPRs has been that a developing country tends to lose from strengthening IPRs and, if it does tighten its protection for IPRs, it is due to pressures from the developed world. In other words, if there is a trade off for a developing country in its choice of IPRs, it is largely the need to gain access to

[11] See Lee(1996) and Dinardo and Tobias(2001) for more detail.

foreign technologies/markets versus the benefits from imitation. In this paper, we have focused on a different trade-off: the need to facilitate imitation and the need to provide incentives for domestic innovative activities. We believe that the benefits from IPRs to a developing country are actually much more than encouraging domestic innovation in the narrow sense. As Stiglitz(1989) has suggested, the lack of a functioning market system could be the biggest obstacle to the development of an economy. The respect for property rights in general, and for IPRs in particular, can be crucial for the establishment of a well-functioning market system and can thus be crucial to economic development.[12] The positive effects of IPRs on domestic innovations, therefore, should be viewed as part of broader effects on entrepreneurial activities. Our analysis suggests a range of common interests between the North and the South in promoting IPRs in the South. This is not to say that there exists no conflict in their interests; in fact, our theory suggests that there could be less incentive to protect IPRs for countries with lower innovative abilities (lower levels of development). But as more developing countries recognize the importance of encouraging entrepreneurial (innovative) activities by domestic firms, the range of common interests between developing and developed countries in promoting IPRs will broaden. Thus, in the long-run, perhaps the best way for the North to promote IPRs in the South is to help the South increase innovative activities.

[12] This is consistent with the view that property rights are important in providing investment incentives and, more generally, the preconditions for economic growth. See Besley (1995).

APPENDIX

Table A1 : Developing countries included in the data set*

Algeria	India	The Philippines
Argentina	Indonesia	Portugal
Bangladesh	Iran	Rwanda
Bolivia	Israel	Sierra Leone
Botswana	Jamaica	Singapore
Brazil	Jordan	Somalia
Burundi	Kenya	South Africa
Chile	Madagasca	South Korea
Colombia	Malaysia	Sri Lanka
Costa Rica	Malawi	Syria
Cyprus	Mali	Tanzania
Dominican Republic	Malta	Thailand
Ecuador	Mauritius	Trinidad and Tobago
Egypt	Mexico	Tunisia
El Salvador	Morocco	Turkey
Fiji	Nepal	Uganda
Ghana	Nicaragua	Uruguay
Greece	Nigeria	Venezuela
Guatemala	Pakistan	Zambia
Haiti	Panama	Zimbabwe
Honduras	Paraguay	
Hong Kong	Peru	

*Based on the classification in World Investment Report 1995, UN and the selections in Maskus(2000)

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