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Private Incentives and Public Protection
for Intellectual Property Rights

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Private Incentives and Public Protection for Intellectual Property Rights*

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Abstract

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1 Introduction

The critical role of intellectual property protection in encouraging innovation at the firm level or country level has long been recognized in the theoretical literature on economic growth. A great many growth models have investigated effects of intellectual property rights (IPR) protection on innovation and growth by focusing on the legal IPR policies implemented by governments (e.g., Helpman 1993; Horowitz and Lai 1997; Futagami and Iwaisako 2007). However, the *effective* strength of IPR protection depends not only on legal policies but also on private measures taken by firms to prevent imitation of their intellectual property. Firms have strong incentives to reduce the informational spillover to customers and competitors by increasing the sharing of tacit knowledge and introducing technical barriers to copying.

This paper models the private incentive to strengthen *effective* protection of IPR for innovations, and investigates its relationship to public IPR protections and welfare. Put simply, firms can reduce the threat of imitation by investing resources in protection activities such as developing new copy-protection technologies,[1] monitoring illegal copies and use of brand logos, or rapidly filing patent infringement suits. In the context of this model, insufficient legal/public IPR protection induces firms to increase such activities. Thus, private investment in response to weak public policy is an endogenous source of IPR protection. This strengthened protection comes at the cost of increasing resource scarcity for innovation, provided that the resources invested in protection can also be used for knowledge creation. As a consequence, incentives for firms to invest in private protection measures may harm innovation and consumer welfare in the whole economy. We will formally verify this theory in a dynamic setting by showing that the aggregate rate of innovation and world welfare can depend negatively on the effectiveness of private protection activities.

Our theory brings new insights into the prominent North-South debate over the effects of legal IPR protection.[2] The literature on North-South models ex-

[1]Obvious examples include the anti-reuse computer chip included in printer cartridges, the copy protection mechanism in DVDs, and authorized software.

[2]The position typically held by developed countries is reflected in the Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement signed in the Uruguay Round, which specifies minimum standards for public IPR protection. However, many developing countries are calling for a review of the TRIPS Agreement in the Doha Round.

presses two diametrically opposed views. Helpman (1993) presented a dynamic model where strengthening IPR protection in the South decreases the rate of innovation in the North. More recently, many papers have examined the effects of IPR protection under models that include technology transfer through avenues such as foreign direct investment and licensing.[3] Another strand of the literature focuses on static models (e.g., Deardorff 1992, Taylor 1993). In a nutshell, all these analyses find that innovation is a monotonic function of stronger public IPR protection, but the direction of the relationship (positive or negative) varies from model to model.

While the works mentioned above have provided important insights, none of them allow for a *non-monotonic* relationship between stronger IPR protection and innovation. For this reason, none consider *the level of Southern IPR protection that maximizes the rate of innovation in the North*. Furthermore, they do not take into account private activities to protect innovations. This paper presents a simple dynamic framework incorporating all three aspects.

The North-South setting is assumed to be in dynamic general equilibrium. Firms protect their innovations from imitation in the South by investing in private copy protection activities. The potential rate of imitation is determined by the IPR policy of the Southern government. We use this framework to show that the effect of stronger legal IPR protection in the South on the rate of innovation in the North differs for two cases. When the Northern firms engage in private protection activities, stronger IPR policies encourage innovation. When the North does not invest in private protection activities because legal IPR protection is sufficient, however, the trend is reversed. Consequently, the effect of stronger IPR protection on innovation is *non-monotonic*. The rate of innovation is actually maximized at a moderate level of legal IPR protection, which increases as private protection activities become more efficient.

The suggestion that a moderate level of legal IPR protection might maximize the rate of innovation is relatively new to the literature on North-South models,[4] although it is common among innovation models ignoring international technology transfer (Cadot and Lippman 1995, Horowitz and Lai 1996, O'Donoghue and Zweimuller 2004).[5] Thus, the proposed model has novel implications for the

[3]See Taylor (1994), Lai (1998), Yang and Maskus (2001), and Glass and Saggi (2002).

[4]See Akiyama and Furukawa (2009) for the first attempt to prove that the relationship between Southern legal IPR protection and Northern innovation is non-monotonic.

[5]See also Furukawa (2007), Horii and Iwaisako (2007), and Bessen and Maskin (2009). See

North-South policy debate. Enforcing stronger IPR protection in the South, for example through the TRIPS Agreement, may not be better for Northern innovation. This research suggests that a moderate approach is desirable.

The remainder of the paper is organized as follows. Section 2 presents the basic model, and Section 3 identifies the negative impact of private protection activity on innovation and welfare *at the aggregate level*. Section 4 examines the effects of legal IPR protection by Southern governments, and Section 5 concludes.

2 The Model

We consider a dynamic general equilibrium model of the North-South product cycle with a continuum of final consumption goods distributed on the interval $[0, N_t]$. The space of goods expands with endogenous innovations indexed by j, each consisting of a new production technology for manufacturing a new consumer good. The model has two regions: the innovative North and the imitative South. Newly created technologies in the North are gradually transferred to the South through imitation.[6]

2.1 Innovation and Endogenous Protection: A Stochastic Dynamic Programming Approach

We begin by considering incentives to invest in private protection against imitation. In the North there are many competitive R&D firms, which produce innovations in each period t with probability 1 by investing $\frac{1}{\kappa N_{t-1}}$ units of Northern labor at wage rate w_{t-1}^N in period $t-1$. Each R&D firm initially manufactures its product in the North, thereby earning a monopolistic rent in period t, say π_t^N. This rent continues through subsequent periods until the firm's idea is imitated. Imitation activities are assumed to be exogenous and stochastic. Once an innovation is imitated, a perfect copy can be supplied by competitive Southern manufacturers at a relatively low protection cost. Hence, the value V of an innovation introduced in period t is the expectation of a discounted sum of period-t and future monopolistic

Qian (2008) for empirical evidence.

[6] In our model imitation is the only channel for international technology transfer, although it is well known that licensing is also an important factor. See Yang and Maskus (2001) and Tanaka et al. (2007) for technology transfer models of licensing.

profits. Denoting the interest rate in period t by r_t^N, the value of an innovation in period t can be written as:[7]

$$V_t = EX_t \left[\sum_{\tau=t}^{\infty} \left(\prod_{i=t+1}^{\tau} \frac{1}{1+r_{i-1}^N} \right) \pi_\tau^N \right], \tag{1}$$

where EX_t represents the expectation of its argument in period t.

The aim of this paper is to formally describe the endogenous survival of R&D firms in terms of voluntary measures taken against copying and imitation, henceforth referred to collectively as "copy protection activities." We assume that R&D firms can decrease the probability of being imitated by investing labor resources in copy protection. Each innovator manages this trade-off to maximize the expectation of his or her intertemporal value. We denote the probability that each innovator survives at the beginning of period t as $s_t \in [0, 1]$, and call s_t the survival rate. This rate is a function of two variables: the level of investment in copy protection activities and the strength of legal IPR protection in the South. Specifically, when the innovator invests $\frac{z_{t-1}}{\lambda N_t}$ units of labor in copy protection in period $t-1$, the survival rate in period t is:

$$s_t = \min \left\{ \frac{1}{\alpha} (z_{t-1} + \phi)^\alpha, 1 \right\}, \qquad 0 < \alpha < 1, \tag{2}$$

where z_{t-1} is the intensity of copy protection activities in period $t-1$, λ is the efficiency of the protection technology, and $\phi > 0$ can be any exogenous variable that positively affects the survival of innovation.[8] We interpret ϕ as the strength of Southern legal IPR protection.[9] In this expression, we assume that stronger legal protection discourages firms from investing in private copy protection activities by making their innovations safer from imitation.[10]

[7]We assume that $\prod_{q=a}^{b} = 1$ whenever $a > b$.

[8]To ensure $s_t \leq 1$ in the case of no copy protection ($z_t = 0$), we assume that $\phi \leq \alpha^{\frac{1}{\alpha}}$.

[9]This approach to modeling IPR protection captures patent breadth; see, for example, Helpman (1993), Eaton and Kortum (1999), Kwan and Lai (2002), and Furukawa (2007). The patent length approach has been formally established by Futagami and Iwaisako (2007). More broadly, our approach analytically applies Yano's (2008, 2009) market quality theory to the description of incomplete intellectual property markets in a dynamic general equilibrium setting. See also Yano and Furukawa (2009) for the quality of intellectual property markets as a fundamental source of past industrial revolution cycles.

[10]A negative relationship between IPR protection and copy protection activities is reasonable, but the alternative case where IPR and the copy protection activities are complements is investigated in the Appendix.

We are now ready to describe the intertemporal behavior of R&D firms in the North. Taking into account the definition of the survival rate, equation (1) can be rewritten as:

$$V_t = \max_{\{z_\tau\}_{\tau=t}^{\infty}; z_\tau \geq 0} \sum_{\tau=t}^{\infty} \left(\prod_{i=t+1}^{\tau} \frac{s_i}{1+r_{i-1}^N} \right) \left(\pi_\tau^N - \frac{w_\tau^N z_\tau}{\lambda N_\tau} \right). \tag{3}$$

This is a concave, nonlinear dynamic programming problem. It can be solved using the recursive method, for which it is beneficial to define a new variable: $R_t \equiv \frac{V_{t+1}/(1+r_t^N)}{w_t^N/\lambda N_t}$, where R_t can be interpreted as "the return rate of copy protection investment in period t." The following theorem shows that the optimal behavior of Northern R&D firms for survival is determined by just two factors: the strength of legal IPR protection in the South and the return rate of copy protection investment, ϕ and R_t.

Theorem 1 *The equilibrium policy function for the nonlinear dynamic programming problem (3) is given by:*

$$z_t^* = \begin{cases} 0 & \textit{if } R_t^{\frac{1}{1-\alpha}} < \phi \\ R_t^{\frac{1}{1-\alpha}} - \phi & \textit{if } \phi \leq R_t^{\frac{1}{1-\alpha}} \leq \alpha^{\frac{1}{\alpha}} \\ \alpha^{\frac{1}{\alpha}} - \phi & \textit{if } \alpha^{\frac{1}{\alpha}} < R_t^{\frac{1}{1-\alpha}} \end{cases}. \tag{4}$$

Proof. To determine the optimal path for $\{z_\tau\}_{\tau=t}^{\infty}$, we derive the Bellman equation for V_t from (3). Then we have:

$$V_t = \max_{z_t} \left\{ \left(\pi_t^N - \frac{w_t^N z_t}{\lambda N_t} \right) + \frac{s(z_t)}{1+r_t^N} V_{t+1} \right\}, \tag{5}$$

subject to (2) and the inequality condition $0 \leq z_t \leq \alpha^{\frac{1}{\alpha}}$. This is a concave, nonlinear maximization problem with only one choice variable z_t. The Lagrangian function is

$$L(z_t, \mu) = V_t + \mu_1 \left(\alpha^{\frac{1}{\alpha}} - z_t \right) + \mu_2 z_t,$$

where μ_1 and μ_2 are Lagrangian multipliers. The Karush–Kuhn–Tucker solution to this problem is

$$\begin{aligned} -\frac{w_t^N}{\lambda N_t} + (z_{t-1} + \phi)^{\alpha-1} \frac{V_{t+1}}{1+r_t^N} &= -\mu_1 - \mu_2 \leq 0 \\ \mu_1 \left(\alpha^{\frac{1}{\alpha}} - z_t \right) &= 0 \\ \mu_2 z_t &= 0 \end{aligned}$$

with $\mu_1 \geq$ and $\mu_2 \geq 0$. Together with the definition of R, these equations lead to (4). It can be shown that the transversality condition is satisfied when $s(z)$ is uniformly bounded. In the present model, the function s is defined to be uniformly bounded. ■

Figure 1(a) shows the effects of the rate of return on copy protection investment (R_t) and legal IPR protection (ϕ) on the optimal level of investment in copy protection (z_t^*). Copy protection investment always increases with its return rate, and decreases with tighter legal protection of IPR in the South: $\frac{\partial z_t^*}{\partial R_t} \geq 0$ and $\frac{\partial z_t^*}{\partial \phi} \leq 0$. The latter property implies that legal protection and private protection are substitutes. (The case in which they are complements is analyzed in the Appendix.)

We next characterize the equilibrium survival rate of R&D firms, s_t^*. By substituting (4) into (2), we obtain the following:

$$s_{t+1}^* = \begin{cases} \frac{1}{\alpha}\phi^{\alpha} & \text{if } R_t^{\frac{1}{1-\alpha}} < \phi \\ \frac{1}{\alpha}R_t^{\frac{\alpha}{1-\alpha}} & \text{if } \phi \leq R_t^{\frac{1}{1-\alpha}} \leq \alpha^{\frac{1}{\alpha}} \\ 1 & \text{if } \alpha^{\frac{1}{\alpha}} < R_t^{\frac{1}{1-\alpha}} \end{cases} . \tag{6}$$

This result shows that the equilibrium survival rate increases with the return rate on copy protection investment and also with the strength of legal IPR protection in the South (Figure 1(b)). *Strengthening legal IPR protection in the South reduces incentives for R&D firms in the North to invest in copy protection activities, and encourages the survival of innovations. A higher rate of return on copy protection investment encourages both private copy protection activities and the survival of innovations.*

It is worth pointing out that the model predicts three different levels of copy protection investment, as shown in Figure 1. The case of no investment is associated with a low rate of return on copy protection activities. Put simply, the rate of return is so low that R&D firms decide it is not worth their while to invest. In the second case, a survival rate equal to one is associated with a higher rate of return on copy protection. In this scenario copy protection activities guarantee survival, so firms always choose to invest. In the intermediate case, the level of copy protection investment is sensitive to the rate of return. Here the inequality condition $0 \leq z_t \leq \alpha^{\frac{1}{\alpha}}$ is not binding.

The equilibrium survival rate of an innovation s_t^* is determined by the level of legal IPR protection in the South, ϕ, and the equilibrium intensity of copy protection activities among Northern R&D firms, z_t^*. We call this endogenous survival rate the "appropriability" of innovations.[11]

2.2 North-South Environment

Our North-South framework is similar to that of Helpman (1993). N_t^N denotes the number of R&D firms that survive in period t plus the number of R&D firms that innovate in period t. $N_t - N_t^N$ denotes the number of imitated products.

In each region there is an infinitely lived representative consumer who inelastically supplies L^i units of labor in each period.[12] This consumer is endowed with the utility function $U = \sum_{t=0}^{\infty} \beta^t \ln u_t$, where u_t is defined as a constant elasticity of substitution utility function on the continuum of final goods: $u_t = \left(\int_0^{N_t} x_t(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}$ where $\sigma > 1$. It is well known that the corresponding dynamic optimization problem has a solution that yields the Euler equation: $\frac{E_{t+1}^N}{E_t^N} = \beta(1 + r_t^N)$, where E_t^N represents spending by Northern consumers in period t. Following Helpman (1993) and many others, it is assumed that financial capital does not flow between the two regions.

Assume that a unit of good j can be manufactured from a unit of labor. If the good j is not imitated, it is monopolistically manufactured by (surviving) Northern monopolistic firms at price $p_t^N = \frac{\sigma w_t^N}{\sigma-1}$. The monopolists supply x_t^N units of the good and earn temporary profits of $\pi_t = \frac{p_t^N x_t^N}{\sigma}$. When good j is imitated, its production technology is transferred to the South.[13] From then on, good j is manufactured at price $p_t^S = w_t^S$. The competitive Southern firms supply x_t^S units of the good and earn no profit, because the technology offers the constant returns to scale.

The assumed lack of capital flow also implies a balanced trade account, $E_t^N =$

[11] See Teece (1986) for more discussion on the concept of appropriability. In this study, we define appropriability as the ability of a firm to capture profits from its intellectual properties. See also Pisano (2006) for a recent discussion on *endogenous* appropriability.

[12] Some important models assume overlapping generations rather than infinitely-lived agents; see Tanaka and Iwaisako (2009).

[13] As is standard (e.g., Helpman, 1993), we focus only on the case where $w^N > w^S$ holds in equilibrium. To ensure this situation, it suffices to assume that L^S is sufficiently large.

$N_t^N p_t^N x_t^N$. We define the innovation rate as $g_t \equiv \frac{\Delta N_t}{N_t} = \frac{N_{t+1}-N_t}{N_t}$ and the fraction of surviving firms as $h_t \equiv \frac{N_t^N}{N_t}$. The market-clearing condition is therefore represented by

$$L^N = N_t^N x_t^N + \frac{g_t}{\kappa} + \frac{z_t^* h_t}{\lambda}. \tag{7}$$

As is standard, we assume free entry into the R&D market. The nonarbitrage condition for R&D activities is given by:

$$\frac{V_t}{1+r_{t-1}^N} = \frac{w_{t-1}^N}{\kappa N_{t-1}}. \tag{8}$$

It follows that the return rate for copy protection investment, R_t, is equal to the efficiency of copy protection technology relative to R&D technology: $R_t = \frac{\lambda}{\kappa}$. The economic intuition behind this statement is quite straightforward. If copy protection technology is more efficient than innovation (λ is larger than κ), then the rate of return on copy protection is larger. If R&D technology is more efficient (κ is larger), on the other hand, more R&D firms enter the marketplace and more innovations take place. This situation decreases the price of innovation (i.e., the present value V), reducing the incentive for active R&D firms to protect their innovations. Taken together, the property $R_t = \frac{\lambda}{\kappa}$, Theorem 1 and equation (6) proves that the mean level of private investment in IPR protection and the appropriability (survival rate) of innovations are time-invariant. That is, we have $z_t^* = z^*$ and $s_t^* = s^*$ in the market equilibrium.

2.3 Steady-State Equilibrium

We now characterize the dynamic general equilibrium of the model, starting with the fraction of monopolistic Northern goods, h_t. In period $t+1$, as shown above, $s^* N_t^N$ innovators survive and ΔN_t innovations are newly introduced into the marketplace. The evolution of h_t is given by

$$h_{t+1} = \frac{s^* h_t + g_t}{1+g_t}. \tag{9}$$

In a balanced growth path (BGP), N, N^N, w^i, and E^i grow at constant rates. Analysis of a BGP is straightforward. Taking into account $h_{t+1} = h_t$ and $v_{t+1} =$

v_t, and using (5), (7), (8), and (9), the innovation rate g^* in a BGP is uniquely determined by the following (the proof is given in the Appendix):

$$\frac{g^* + 1 - s^*}{g^*} = \frac{(\sigma - 1)(1 + g^*)/\beta - (\sigma - 1)s^* + \sigma\kappa z^*/\lambda}{\kappa L^N - g^*}.^{14} \tag{10}$$

We are now ready to run various comparative statics experiments. The following sections investigate the effects of private copy protection investment and legal IPR protection on the appropriability of innovation and the overall rate of innovation in a dynamic equilibrium.

3 The Role of Private Incentives for IPR Protection in Innovation and Welfare

In the previous section, we described our model of endogenous IPR protection. The innovation rate, level of private investment in copy protection, and appropriability (i.e., survival rate) of innovation in the unique BGP are endogenously determined by (4), (6), and (10) respectively. We will use these equilibrium conditions to investigate the roles of private and legal/public IPR protection in innovation and welfare.

The fundamental question of this paper is whether incentives for private R&D firms to protect their innovations against imitation positively affect the rate of innovation and economic welfare. Although at the firm level it is clear that private protection increases the appropriability of an innovation, increasing the incentive to innovate, the relationship is not so clear at the aggregate level. In this section, we will investigate the macroeconomic consequences of private incentives for IPR protection. Specifically, we will examine the effects of an increase in the efficiency of protection technology on the rate of innovation and consumer welfare at the aggregate level.

Figure 2 describes the relationships between the efficiency of a protection technology (λ) and the rate of innovation (g^*), the level of private protection investment (z^*/λ) and the appropriability of innovation (s^*), as given in equations

[14]The left-hand side of this equation is decreasing in g and converges to infinity as $g \to 0$. The right-hand side is strictly increasing in g. This property guarantees the uniqueness of a BGP. Note that z^* and s^* are determined by Theorem 1 and (6) respectively, with $R_t = \frac{\lambda}{\kappa}$.

(4), (6), and (10) respectively. For simplicity, we normalize κ to unity in this section.

As shown in Figure 2, the effects of an increase in λ depend on the initial level of the efficiency. We observe three distinct cases. First, when the technology is initially very inefficient $\left(\lambda < \phi^{1-\alpha}\right)$, increasing λ does not affect the level of protection investment z^*/λ or the appropriability s^*. In this case, the rate of innovation g^* does not depend on the efficiency of the protection technology. Second, when the technology is initially very efficient ($\alpha^{\frac{1-\alpha}{\alpha}} < \lambda$), the appropriability goes to 100% ($s^* = 1$) and stays there. However, increasing the efficiency of the protection technology further decreases the amount of protection investment z^*/λ and increases the rate of innovation g^*.[15]

The third case is more complicated. For intermediate efficiency levels ($\lambda \in (\phi^{1-\alpha}, \alpha^{\frac{1-\alpha}{\alpha}})$), an increase in λ increases both protection investment and appropriability. Taken together, these two impacts may decrease the rate of innovation g^*. A negative relationship between λ and g^* holds in a neighborhood around the lower boundary of this region, $\lambda = \phi^{1-\alpha}$. The right-hand side of (10) is continuous and increasing in λ at $\lambda = \phi^{1-\alpha}$, which implies that g^* is decreasing in λ.[16] Put another way, *the rate of innovation decreases when the efficiency of private protection activities increases to the point that firms begin investing.*

More generally, we can derive a sufficient condition for the case where a negative relationship between λ and g^* exists for all $\lambda \in (\phi^{1-\alpha}, \alpha^{\frac{1-\alpha}{\alpha}})$. If $\sigma < \frac{\alpha^{\frac{1}{\alpha}}}{\alpha^{\frac{1}{\alpha}} - \phi}\left(1 + \frac{\alpha}{1-\alpha}\phi^{1-\alpha}\right)$,[17] an increase in λ always decreases the rate of innovation g^* in the intermediate region.

We can summarize the above discussion as follows. (Note that in this model, g^* corresponds to the overall rate of innovation in the world economy.)

Proposition 1 *The relationship between the overall rate of innovation, g^*, and the efficiency of private protection activity, λ, can be negative. In particular, the*

[15] Formally, from (4), (6), and (10), we can show that the rate of innovation is given by $g^* = \frac{\beta L^N - (\sigma-1)(1-\beta) - \beta\sigma z^*/\lambda}{\sigma+\beta-1}$ in the case of $\alpha^{\frac{1-\alpha}{\alpha}} < \lambda$.

[16] Note that the left-hand side of (10) is decreasing in λ.

[17] The condition $\frac{1+\alpha\lambda/(1-\alpha)}{1-\phi\lambda^{-\frac{1}{1-\alpha}}} > \sigma$ ensures that the right-hand side of (10) is globally increasing in λ for all $\lambda \in (\phi^{1-\alpha}, \alpha^{\frac{1-\alpha}{\alpha}})$. After noting that $\lambda \in (\phi^{1-\alpha}, \alpha^{\frac{1-\alpha}{\alpha}})$, the condition $\frac{1+\alpha\lambda/(1-\alpha)}{1-\phi\lambda^{-\frac{1}{1-\alpha}}} > \frac{\alpha^{\frac{1}{\alpha}}}{\alpha^{\frac{1}{\alpha}} - \phi}\left(1 + \frac{\alpha}{1-\alpha}\phi^{1-\alpha}\right) > 1$ can easily be derived.

relationship is U-shaped if $\sigma < \frac{\alpha^{\frac{1}{\alpha}}}{\alpha^{\frac{1}{\alpha}}-\phi}\left(1+\frac{\alpha}{1-\alpha}\phi^{1-\alpha}\right)$*, as shown in Figure 2.*

The intuition for this proposition is as follows. For $\lambda \in [0, \phi^{1-\alpha}]$, the protection technology is too inefficient to attract investment, so a small increase in λ has no effect. We refer to this range as the "highly competitive regime." In the intermediate region, $\lambda \in (\phi^{1-\alpha}, \alpha^{\frac{1-\alpha}{\alpha}})$, increasing λ encourages protection investment z^*/λ and increases the survival rate of innovations s^*,[18] leading to increases in the amount of Northern labor used for copy protection and in the share of production remaining in the North. Because the ultimate effect is to make resources scarcer in the North, more efficient protection technology results in fewer innovations. Within the intermediate region, stronger incentives for firms to protect their innovations will decrease the overall rate of innovation in the world. For $\lambda \in [\alpha^{\frac{1-\alpha}{\alpha}}, \infty)$, the survival rate is 100% (i.e., all innovations are fully appropriable). We call this range the "strong appropriability regime." In this case, increased efficiency frees up Northern labor for production, encouraging innovation. The global relationship between λ and g^* therefore U-shaped: either very efficient or very inefficient copy protection technologies will enhance innovation.

The rate of innovation is likely to be intrinsically high in the two polar cases. In the highly competitive regime, private protection activities for innovations are ineffective so the product (life) cycle is *very short.* Many innovations are introduced daily, and most of them immediately become available at competitive prices (low appropriability) after being transferred to the developing South. The scarce resources for innovation are not wasted on strengthening IPR protection, so a greater number of innovations are introduced.

In the strong appropriability regime innovation is also rapid, but there are two critical costs to the global welfare. First, compared to the highly competitive regime, there are more monopolists, so we should expect greater price distortion and a smaller overall welfare. Second, no technology transfer occurs, so the South is permanently underdeveloped (i.e., the real wage rate and consumption expenditure in the South decline). Consequently, consumer welfare is greater in the highly competitive regime than in the strong appropriability regime.

[18] This effect becomes stronger as σ decreases, because a smaller value of σ implies larger temporary profits from an innovation. The larger the profits, the more incentive firms have to protect their innovation, so an increase in λ is more significant. It is worth pointing out that the inequality condition in Proposition 1 (i.e., σ is sufficiently small) ensures that an increase in λ corresponds to a sufficiently large increase in protection investment, z^*/λ.

In the intermediate region some of the labor resource is used for protection (z^*/λ) to improve the appropriability of innovations, s^*. Both variables are positively related to the efficiency of protection activities, λ, as shown in Figure 2. Resource scarcity and the price distortion increases with λ, because a higher value of s^* leads to a larger share of monopolistic sectors. Therefore, we assert that consumer welfare depends negatively on the efficiency of protection activity in this regime. Since consumer welfare is greater in the highly competitive regime than in the strong appropriability regime, we further predict that consumer welfare is maximized when the efficiency of protection activities falls in the highly competitive regime.

Finally, we have the following implication of Proposition 1.

Remark 1 *Consumer welfare and the overall rate of innovation are higher when the efficiency of protection activity is sufficiently low that private protection activities do not take place* $($*i.e., the highly competitive regime*$)$. *Therefore, we suggest that private incentives to protect innovations harm both innovation and economic welfare at the aggregate level.*

4 Legal/Public IPR Protection

In this section, we will investigate the impacts of stronger legal/public IPR protection by Southern governments on the rate of innovation in the North (i.e., the world rate of innovation). Such impacts have already been investigated intensively in the literature. Although existing models typically find monotonic effects of stronger legal IPR protection on innovation, as mentioned in the introduction, this paper has demonstrated that there is a *non-monotonic* relationship.

Our goal now is to identify a level of IPR protection in the South that maximizes the rate of innovation in the North. First, consider an increase in ϕ on the rate of innovation g^*. Figure 3 shows the relationship between Southern legal protection ϕ and the rate of Northern innovation g^*. For initially weak IPR protection, $\phi \in [0, \left(\frac{\lambda}{\kappa}\right)^{\frac{1}{1-\alpha}}]$, an increase in ϕ makes Northern innovators safer from imitation and thus decreases investment in private protection activities; $\frac{\partial z^*}{\partial \phi} < 0$. We call this the case "with private protection of IPR." The decreased investment in protection releases labor resources for Northern innovation. Thus, tighter Southern IPR protection stimulates innovation in the North (g^*). Note that it is possible to verify this by total differentiation of (10); $\frac{dg^*}{d\phi} > 0$ holds in the case "with private protection," where $\phi \in [0, \left(\frac{\lambda}{\kappa}\right)^{\frac{1}{1-\alpha}}]$.

However, in the area of the plot where $\phi \in [\left(\frac{\lambda}{\kappa}\right)^{\frac{1}{1-\alpha}}, \alpha^{\frac{1}{\alpha}}]$, Southern legal protection is so strong that imitation hardly ever occurs. This implies that Northern innovators no longer have any incentive to spend resources on copy protection, and the level of investment decreases to zero. We call this the case "without private protection of IPR." In this case, tighter legal protection increases the appropriability of innovations, s^*, and depresses international technology transfer by suppressing imitation.[19] Thus, production remains in the North and fewer resources can be devoted to innovation. Hence, there is no mechanism whereby tighter legal IPR protection relaxes resource scarcity in the North: strengthening the Southern policy (increasing ϕ) actually decreases the rate of innovation (g^*). By differentiating (10), we can formally prove that $\frac{dg^*}{d\phi} < 0$ holds in the case "without private protection," where $\phi \in [\left(\frac{\lambda}{\kappa}\right)^{\frac{1}{1-\alpha}}, \alpha^{\frac{1}{\alpha}}]$.

The following statement summarizes these findings.

Proposition 2 *There is an inverted U-shaped relationship between the strength of IPR policy in the South, ϕ, and the rate of innovation in the North, g^*, as shown in Figure 3. The rate of innovation is maximized at $\phi = \left(\frac{\lambda}{\kappa}\right)^{\frac{1}{1-\alpha}}$.*

This sort of relationship between IPR and innovation is relatively new in the literature on North-South models. As mentioned in the introduction, existing models typically show monotonic (positive or negative) relationships, so the *innovation-maximizing* level of legal IPR protection in the South has not been addressed. Hence, this research reconciles the previously reported positive and negative effects of IPR protection on innovation by focusing on the private incentive for firms to protect their intellectual properties.

This result suggests a novel direction for global IPR policies. Both very strong and very weak legal IPR protection in the South will lead to a low innovation rate in the North. Hence, enforcing stronger IPR protection in the South, as would occur under the TRIPS Agreement, is not always better for Northern innovation. Moderate IPR policies are more desirable if the goal is to encourage innovation in the North.

[19] This negative effect of tighter IPR controls on international technology transfer was first found by Helpman (1993).

Proposition 2 also shows that the innovation-maximizing level of legal protection, $\phi = \left(\frac{\lambda}{\kappa}\right)^{\frac{1}{1-\alpha}}$, increases as copy protection technology becomes more efficient (larger λ) and/or when the R&D technology becomes less efficient (smaller κ). It follows that a *weak* IPR policy in the South maximizes the rate of innovation in the North when private copy protection activities are costly (i.e., λ is small) and/or if the start-up cost of innovation is small (i.e., κ is large). The policy implications can be summarized in the following statement:

Remark 2 *Depending on the technological nature of the product, the desirable level of legal IPR protection in the South differs. If products are easy* (*costless*) *to invent, the level of legal protection should be low. If products are easy to protect privately, he level of legal protection should be high.*

5 Conclusion

In this paper we have analyzed the role of private incentives for firms to protect their intellectual property in determining the rate of innovation and general welfare in a dynamic general equilibrium model. We have shown that the strong incentives for firms to develop their own IPR protection measures can have a negative effect on innovation and economic welfare at the aggregate level. In particular, there is a U-shaped relationship between the efficiency of private protection technology and the aggregate rate of innovation. The rate of innovation is high at the two extreme cases, where private protection technology is so inefficient that none exists or where it is so efficient that monopolistic firms always survive (i.e., all innovations are fully appropriable). Due to monopolistic price distortion and the lack of international technology transfer, the global welfare should be smaller in the latter case. The rate of innovation and economic welfare are therefore highest when private copy protection activities are inefficient. We have also identified the level of legal IPR protection that maximizes the rate of innovation. The innovation-maximizing policy becomes stronger as private protection activity becomes more efficient. This result is new to the literature on North-South models, where existing papers have found that strengthening IPR protection has a monotonic (positive or negative) effect of strengthening IPR protection.

Appendix

A. Proof for (10):

Define a new variable $v_t \equiv \frac{N_t V_t}{E_t^N}$, which can be interpreted as the ratio of the asset holding and expenditure in the North. Then, using $E^N = N^N p^N x^N$, (5), (7) and (8), we have:

$$v_{t+1} = \frac{(1+g_t)(v_t - \frac{1}{\sigma h_t})}{\beta\left(s^* - \frac{\kappa}{\lambda}z^*\right)}, \tag{11}$$

where

$$g_t = \kappa L^N - \frac{(\sigma-1)\left(s^* - \frac{\kappa}{\lambda}z^*\right)}{\sigma(v_t - \frac{1}{\sigma h_t})} - \frac{\kappa z^* h_t}{\lambda}. \tag{12}$$

The dynamics of our model for endogenous survival of innovation follows two difference equations, (9) and (11), plus three side conditions, (4), (6), and (12). It can be easily shown from (9) and (11) that the BGP innovation rate is characterized by (10). The difference equation system consisting of (9) and (11) is found to be locally saddle-path stable in many numerical examples.

B. Complementarity between legal and private protection of IPR:

Proposition 2 provides an important policy implication: the enforcement of legal IPR protection toward developing countries, such as the TRIPS Agreement, can hurt innovation in developed countries because there is an inverted-U relationship between legal protection of IPR in the South and the rate of innovation in the North.

The substitutability between legal and private protection of IPR plays a critical role in driving the inverted-U relationship. We can show that if legal protection of IPR by Southern governments and private protection by Northern R&D firms are complements, the result may differ: the relationship between legal IPR protection and innovation can be U-shaped. To see this, we use the specific survival function $s = \frac{\phi z^\alpha}{\alpha}$. In a similar manner, we can derive the equilibrium behavior of innovators and the equilibrium survival rate as follows:

$$z^* = \begin{cases} \phi^{\frac{1}{1-\alpha}} & \text{if } \phi < \alpha^{1-\alpha} \\ \left(\frac{\alpha}{\phi}\right)^{\frac{1}{\alpha}} & \text{if } \phi \geq \alpha^{1-\alpha} \end{cases} \quad \text{and} \quad s^* = \begin{cases} \frac{1}{\alpha}\phi^{\frac{1}{1-\alpha}}, & \text{if } \phi < \alpha^{1-\alpha} \\ 1, & \text{if } \phi \geq \alpha^{1-\alpha} \end{cases},$$

where we normalize $\kappa = \lambda$ for simplicity. Since a strengthening of legal IPR protection, i.e., an increase in ϕ, increases investment in private copy protection, z, in this setting, it can be said that the legal and private factors of IPR protection are complements. From these z^* and s^* in the complementary case, and from (10), we can show that $\frac{dg^*}{d\phi} < 0$ holds for $\phi < \alpha^{1-\alpha}$ since stronger legal IPR increases both z and s and tightens the resource scarcity in the North. We can also show that $\frac{dg^*}{d\phi} \geq 0$ holds for $\phi \geq \alpha^{1-\alpha}$ since stronger legal IPR protection saves resource for z keeping the constant survival rate 100%. Then we have the following proposition.

Proposition 3 *If legal protection of IPR by Southern governments and private copy protection by Northern firms are complements, the relationship between the level of legal IPR protection and the rate of innovation is U-shaped.*

The implication of this proposition is as follows. If a tighter IPR policy stimulates the private copy protection activity of R&D firms (complementarity), then very weak and very strong IPR policies enhance innovation. This result is consistent with the empirical finding of a recent study (Allred and Park 2007). It is worth pointing out that as all new innovations continue to be supplied in monopolistic sectors in the case of very strong legal IPR protection (i.e., $\phi > \alpha^{1-\alpha}$), the case of very weak legal IPR protection could be desirable from the viewpoint of welfare. This delivers the following interesting implication for the patent policies of governments:

Remark 3 *If stronger legal protection of IPR encourages the private copy protection activity by R&D firms, a very weak IPR policy (such as one-period patent protection) could be desirable.*

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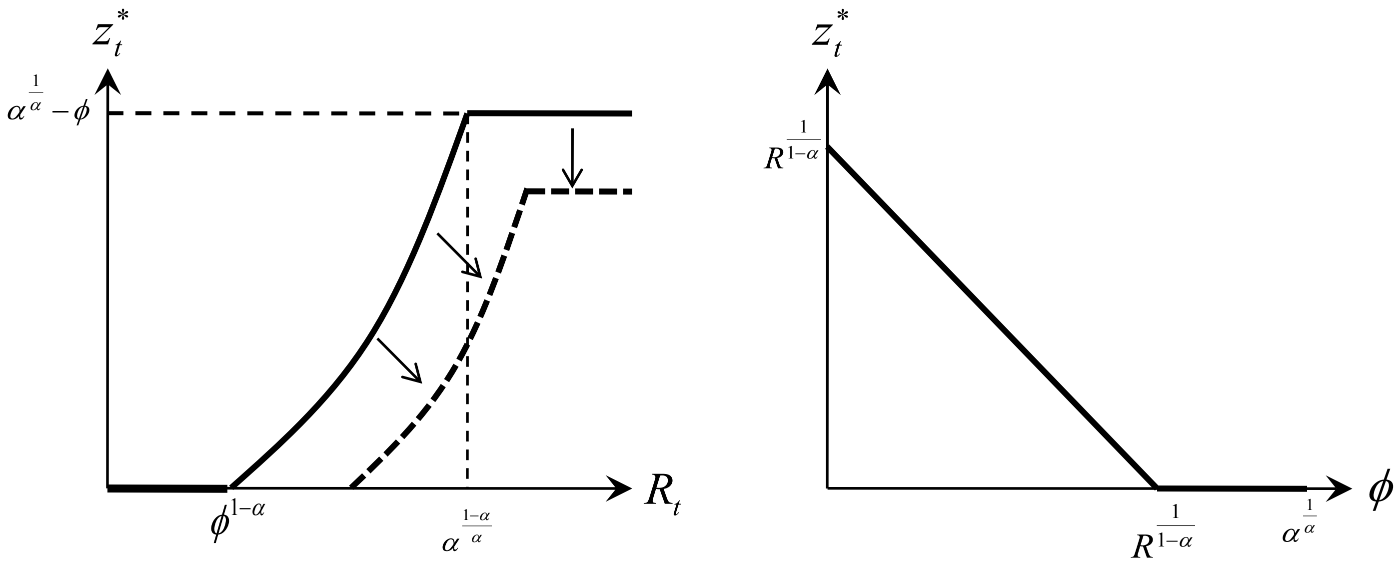
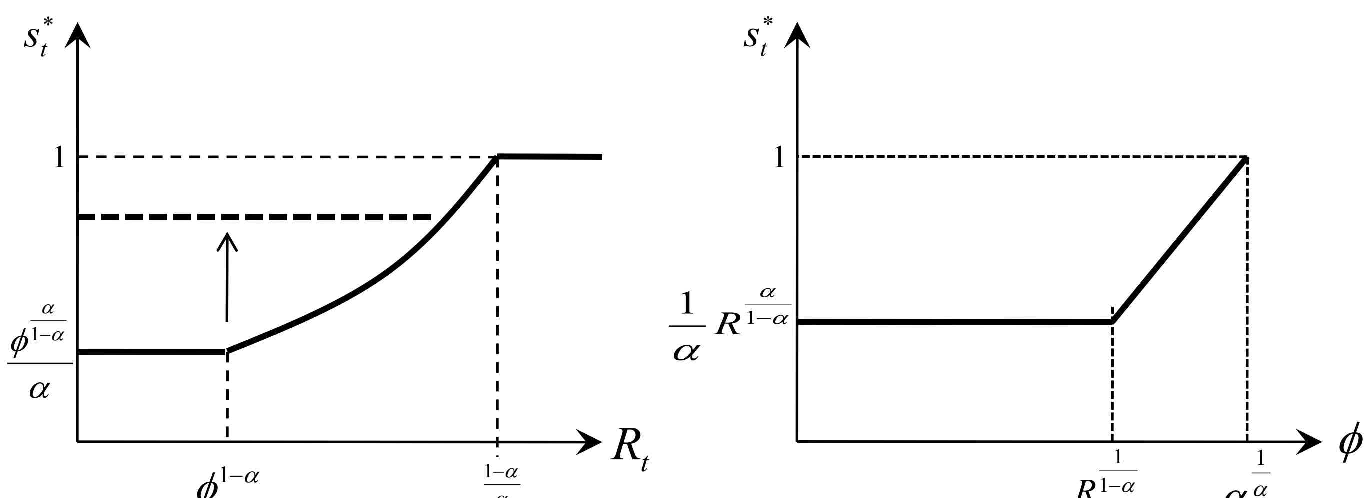


(a) The effects on the optimal level of investment in copy protection



(b) The effects on the equilibrium survival rate of R&D firms

Figure 1: The effects of the rate of return on copy protection investment and legal IPR protection

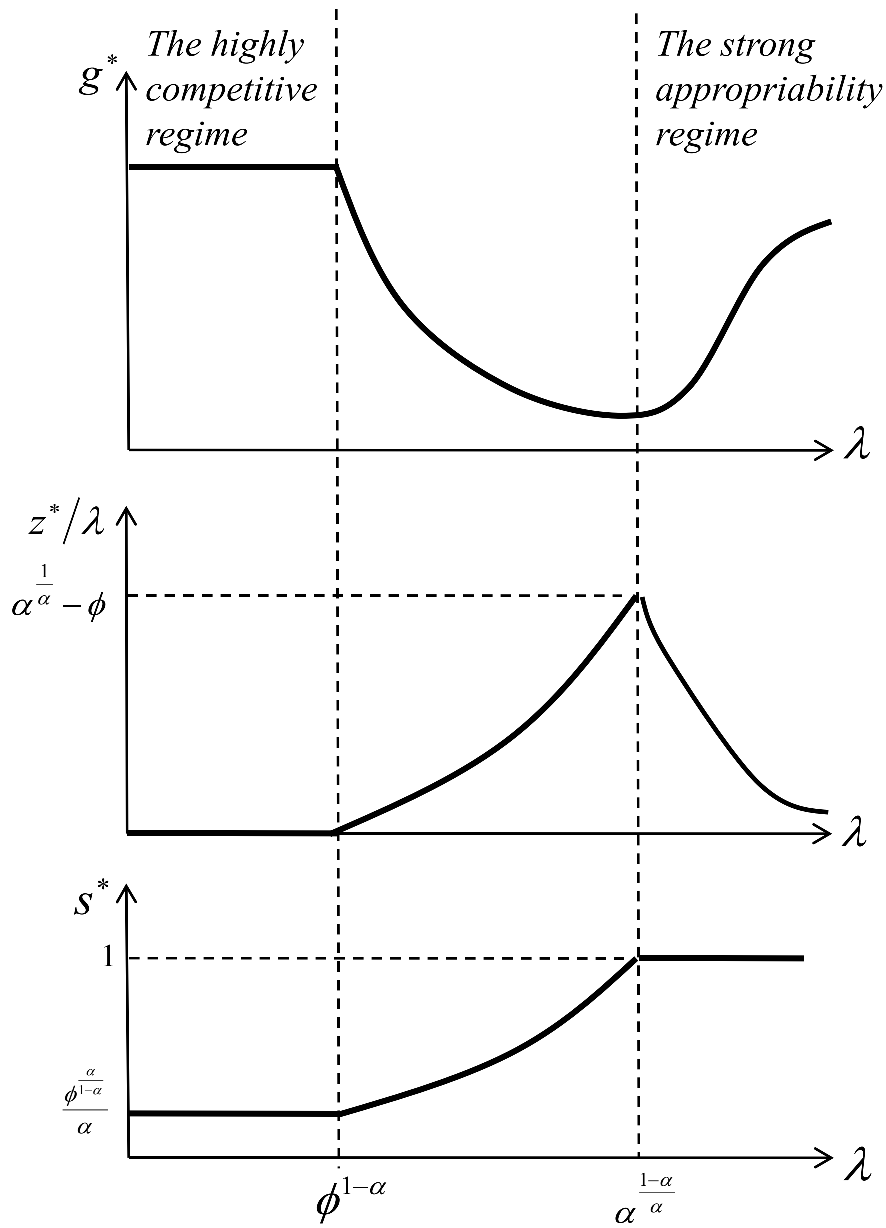


Figure 2: The effects of the efficiency of a protection technology

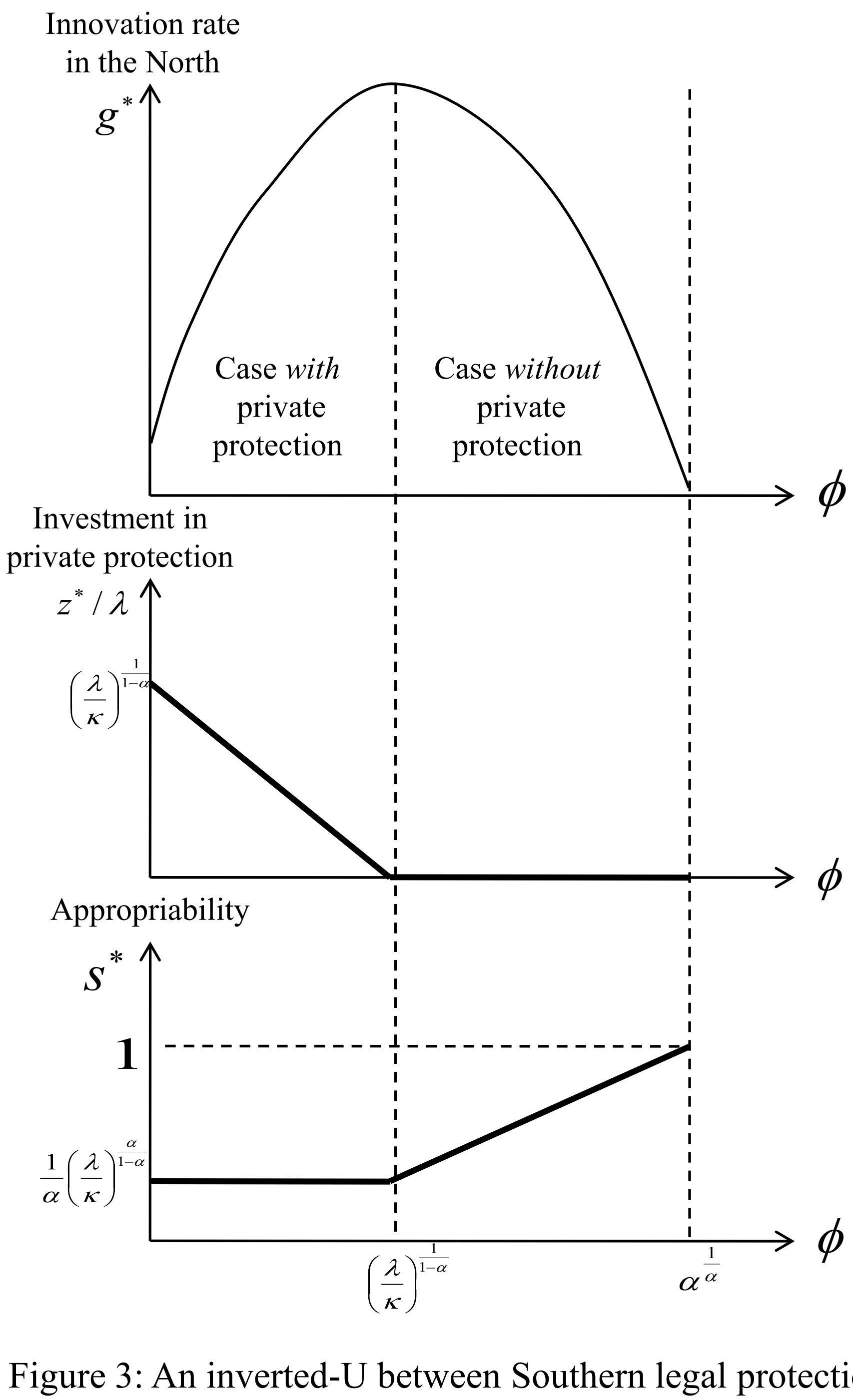


Figure 3: An inverted-U between Southern legal protection and the rate of Northern innovation