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Taro Akiyama
Yokohama National University

Yuichi Furukawa
Chukyo University

Makoto Yano
Kyoto University

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Taro Akiyama
Yokohama National University

Yuichi Furukawa†
Chukyo University

Makoto Yano
Kyoto University

Abstract

This paper investigates the private defense of intellectual properties in a standard North-South endogenous growth model in which R&D activities are endogenized. It identifies two major factors determining whether or not private defense activities contribute to economic growth: (i) The relative cost between private defense and innovation and (ii) the strength of intellectual property laws in the South.

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†Corresponding author. Email: you.furukawa@gmail.com (Y. Furukawa)

1 Introduction

Recently, the private defense of intellectual properties has become increasingly important for many private companies. For example, as Jaffe and Lerner (2004) note, companies in the United States spend over $100 billions on R&D each year for private defense. According to them, "These expenditures have been growing across almost every industry from traditional manufacturing to services to high technology." Companies that do businesses in developing countries such as China and India "face numerous difficulties protecting or even defining their intellectual property" due to the underdevelopment of intellectual properties (PricewaterhouseCoopers 2008).

One direct effect of private defense activities for R&D firms to protect their own intellectual properties is to reduce the resources that could be spent on innovation. Therefore, it can be expected that, as they become more and more important, private defense activities will have a serious negative impact on economic growth. Despite this, the mechanism through which the suppressive effect of private defense activities might emerge has not been examined in the existing literature on endogenous growth. The present study intends to take the first step towards filling this void.

For this purpose, we extend the standard North-South model of endogenous growth developed by Grossman and Helpman (1991, Ch. 11) and Helpman (1993) by incorporating private defense activities to protect intellectual properties. Using this model, we reveal that whether or not the private defense of intellectual properties is in fact detrimental to economic growth depends on two key economic parameters: (i) The relative cost between private defense and innovation and (ii) the strength of intellectual property laws in the South.

An important policy finding of this study is that, under the presence of private defense activities, the development of intellectual property laws in the South may stimulate innovation in the North. This finding makes an interesting contrast with the work of Helpman (1993), which shows that the strengthening of intellectual property protection in the South tends to decrease the rate of innovation in the North. Their work has been extended by a number of studies, in which the strengthening of intellectual property protection in the South is shown to have mixed effects.[1] We will extend this

[1] See Lai (1998), Glass and Saggi (2002), Yang and Maskus (2001), Glass and Wu (2007), Dinopoulos and Segerstrom (2010), and Akiyama and Furukawa (2009).

line of studies by bringing in the private defense of intellectual properties.

Our study is a contribution to the vast literature on intellectual property protection in R&D-based growth models. This literature originates from Romer (1990) and have been developing rapidly.[2]

Broadly speaking, our study is related to the vast literature on the international spillover of technological progress, to which Kemp (1955) has made several pioneering contributions. In the early literature, which focuses on the terms-of-trade effect, Kemp (1955) has given the first formal characterization by extending Hicks (1953). Subsequently, he has extended that literature to cover innovation and the transfer of technologies (see Chiarella, Kemp, and Long (1989)). In that their study adopts a microeconomic leader-follower model, it differs from the endogenous growth approach that has been taken in the recent literature, including the present study.

In what follows, we will present the basic model in Section 2. In Section 3, we will investigate the role of private defense activities in economic growth.

2 Model of Imitation and Private Defense

We will incorporate private defense activities to protect intellectual properties into Helpman's North-South model (Helpman, 1993). Assume that there is 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. Innovation takes place only in the North. Newly invented technologies in the North are transferred to the South through imitation.

In the North, there are many competitive R&D firms. In order for a firm to make an invention in period t, it is necessary to employ $\frac{1}{\kappa N_{t-1}}$ units of Northern labor in period $t-1$. Each firm makes one, and only one, invention. Once labor input is made, an invention is successful with probability 1.

Each of R&D firms monopolistically manufactures its product in the North until its invention is imitated in the South. Denote as π_τ^N the monopolistic rent that an R&D firm makes in period τ in the case in which

[2] See Cozzi (2001), Li (2001), Iwaisako and Futagami (2003), O'Donoghue and Zweimuller (2004), Kwan and Lai (2003), Cozzi and Spinesi (2006), Furukawa (2007), Futagami and Iwaisako (2007), Horii and Iwaisako (2007), Chu (2009, 2010), and Chu and Furukawa (2011).

its invention is not yet imitated in period τ. (This profit is endogenously determined, as is explained below.)

In our model, technologies that are invented in the North diffuse through imitation that firms in the South make. Once the product is imitated in the South, it is competitively produced by many firms in the South.[3] Assume that imitation takes place through a simple Poisson process with a survival rate s_t and that this rate of survival is increased both by private defense activities and the strength of intellectual property laws in the South. That is to say, the product of an R&D firm in the North (that has not yet been imitated at the beginning of period t) is imitated in period t with probability $1 - s_t$. The firm can reduce this probability by engaging in a private defense activity, denoted by z_t. The probability of imitation is reduced also by the strength of intellectual property laws in the South, denoted by ϕ. More specifically, assume

$$s_t = \min\left\{\sqrt{z_{t-1} + \phi}, 1\right\}. \tag{1}$$

In order to ensure $s_t \leq 1$ in the case of no private defense efforts ($z_{t-1} = 0$), we assume that $\phi \leq 1$. This specification of an imitation process extends Helpman (1993). It is new in that private defense efforts for intellectual property protection, z_{t-1}, can influence the survival rate of an intellectual property against imitation, s_t.

Assume that in order to engage in a private defense activity, z_{t-1}, an R&D firm must employ $\frac{z_{t-1}}{\lambda N_{t-1}}$ units of labor in period $t-1$. So long as a firm holds an invention that is not yet imitated, *it will sell the corresponding product monopolistically.* Denote as w_t^N the wage rate in period t. Then, the cost of this investment is $\frac{w_\tau^N z_\tau}{\lambda N_\tau}$.

Denote as V_t the value of a firm that holds in period t an invention that is not yet imitated. This value is equal to the expected value of discounted sum of present and future monopolistic rents. By denoting as r_t^N the interest rate in period t, a firm's value can be expressed as

$$V_t = \max_{\{z_\tau\}_{\tau=t}^{\infty}; z_\tau \geq 0} \sum_{\tau=t}^{\infty} \left(\prod_{i=t+1}^{\tau} \frac{s_i}{1 + r_{i-1}^N} \right) \left(\pi_\tau^N - \frac{w_\tau^N z_\tau}{\lambda N_\tau} \right). \tag{2}$$

This is a concave, nonlinear dynamic programming problem. In order to solve this problem by the standard recursive method, it is useful to define

[3] This may be thought of either as an assumption or as a market phenomenon. See Helpman (1993) for the latter explanation.

a new variable $R_t \equiv \frac{V_{t+1}/(1+r_t^N)}{w_t^N/\lambda N_t}$, which can be interpreted as the potential benefit of private defense.

The lemma below shows that the optimal behavior of Northern R&D firms for survival is determined by just two factors: the strength of intellectual property laws in the South, ϕ, and the potential benefit of private defense, R_t.

Lemma 1 *The equilibrium intensity of private efforts for protecting intellectual properties is given by:*

$$z_t^* = \begin{cases} 0 & \text{if } (R_t)^2 < 4\phi \\ \frac{1}{4}(R_t)^2 - \phi & \text{if } 4\phi \leq (R_t)^2 \leq 4 \\ 1-\phi & \text{if } 4 < (R_t)^2 \end{cases} . \tag{3}$$

Proof. To determine the optimal path for $\{z_\tau\}_{\tau=t}^{\infty}$, we derive the Bellman equation for V_t from (2). Then we have:

$$V_t = \max_{z_t} \left\{ \left(\pi_t^N - \frac{w_t^N z_t}{\lambda N_t} \right) + \frac{s(z_t)}{1+r_t^N} V_{t+1} \right\}, \tag{4}$$

subject to (1) and the inequality condition $0 \leq z_t \leq 1-\phi$. This is a concave, nonlinear maximization problem with only one choice variable z_t. The Lagrangian function is

$$L(z_t, \mu) = V_t + \mu_1 (1 - \phi - z_t) + \mu_2 z_t,$$

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

$$\begin{aligned} -\frac{w_t^N}{\lambda N_t} + \frac{1}{2\sqrt{z_t+\phi}} \frac{V_{t+1}}{1+r_t^N} &= -\mu_1 - \mu_2 \leq 0 \\ \mu_1 (1-\phi-z_t) &= 0 \\ \mu_2 z_t &= 0 \end{aligned}$$

with $\mu_1 \geq$ and $\mu_2 \geq 0$. Together with the definition of R, these equations lead to (3). 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. ■

Equation (3) reveals that private defense intensity z_t^* unambiguously increases with the potential benefit of private defense R_t ($\frac{\partial z_t^*}{\partial R_t} \geq 0$). Moreover, it decreases as the strength of intellectual property laws in the South ϕ increases ($\frac{\partial z_t^*}{\partial \phi} \leq 0$), which implies that R&D firms in the North can save resources invested in private defense as intellectual property laws are strengthened in the South. By substituting (3) into (1), we obtain the following:

$$s_{t+1}^* = \begin{cases} \sqrt{\phi} & \text{if } (R_t)^2 < 4\phi \\ R_t & \text{if } 4\phi \leq (R_t)^2 \leq 4 \\ 1 & \text{if } 4 < (R_t)^2 \end{cases} . \tag{5}$$

Assume that there is no international capital flow and that a borrowing and lending market exists in each region. In each region, moreover, there is an infinitely lived representative consumer who inelastically supplies L^i units of labor in each period. 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: $\frac{E_{t+1}}{E_t} = \beta(1 + r_t)$, where $E_t = \int_0^{N_t} p_t(j)x_t(j)dj$ represents spending by the representative agent in the region in period t.

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 R&D firms in the North at price $p_t^N = \frac{\sigma w_t^N}{\sigma-1}$. Denote as N_t^N the number of products supplied by those firms, which is equal to the sum of the number of inventions that has not yet been imitated in period t and that of new inventions in period t. 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.[4] From then on, good j is manufactured at price $p_t^S = w_t^S$ by the competitive Southern firms, which supply x_t^S units of the good.

We define the growth rate of technologies as $g_t \equiv \Delta N_t/N_t = (N_{t+1} - N_t)/N_t$ and the fraction of surviving firms as $h_t \equiv N_t^N/N_t$. With this nota-

[4] 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.

tion, the labor market clearing condition can be written as

$$L^N = N_t^N x_t^N + \frac{g_t}{\kappa} + \frac{z_t^* h_t}{\lambda}. \tag{6}$$

Following the standard literature, we assume free entry for the R&D market. The non-arbitrage condition for R&D activities is given by

$$\frac{V_{t+1}}{1+r_t^N} = \frac{w_t^N}{\kappa N_t}. \tag{7}$$

Since $R_t = \frac{V_{t+1}/(1+r_t^N)}{w_t^N/\lambda N_t}$ by definition, (7) implies

$$R_t = \frac{\lambda}{\kappa}. \tag{8}$$

In order to characterize the dynamic general equilibrium in our model, first, note that $R_t = \lambda/\kappa$ is time independent. This implies, by Lemma 1 and equation (5), that, in equilibrium, the intensity of private defense efforts and the survival rate of intellectual properties are time independent as well. Thus, we may write $z_t^* = z^*$ and $s_t^* = s^*$.

In period $t+1$, as shown above, $s^* N_t^N$ innovators survive, and ΔN_t innovations are newly introduced in the market. Since $N_{t+1}^N = s^* N_t^N + \Delta N_t$, the evolution of h_t is given by

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

Define a new variable $v_t \equiv N_t V_t / E_t^N$, which is the ratio of the asset holding and expenditure in the North. Under the assumption that there is no international capital market, it holds that $E_t^N = N_t^N p_t^N x_t^N$. By using this relationship together with (4), (6) and (7), we have

$$v_{t+1} = \frac{(1+g_t)(v_t - \frac{1}{\sigma h_t})}{\beta\left(s^* - \frac{\kappa}{\lambda} z^*\right)} \tag{10}$$

with

$$g_t = \kappa L^N - \frac{(\sigma-1)\left(s^* - \frac{\kappa}{\lambda} z^*\right)}{\sigma(v_t - \frac{1}{\sigma h_t})} - \frac{\kappa z^* h_t}{\lambda}. \tag{11}$$

Given (11), equations (9) and (10) constitute a dynamical system with two state variables, v_t and h_t, which represents our equilibrium system.

3 Private Defense Efforts and Growth

Recall that parameters λ and ϕ, respectively, represent how effective private defense efforts for protecting intellectual properties are how sophisticated intellectual property laws are in the South. In this section, we will investigate how these parameters affect the balanced growth rate of technological progress, g^*. We call this rate, g^*, simply a balanced growth rate in the North, since the period-wise utility in the North, $\ln u_t$, grows at this rate g^* on a balanced growth path.

The main result of this study is captured by the theorem below.

Theorem 1 *The balanced growth rate is uniquely determined as*

$$\frac{g^* + 1 - s^*}{g^*} = \frac{(\sigma - 1)(1 + g^*)/\beta - (\sigma - 1)s^* + \sigma\kappa z^*/\lambda}{\kappa L^N - g^*}, \tag{12}$$

where

$$z^* = \begin{cases} 0 & \text{if } \frac{\lambda}{\kappa} < 2\sqrt{\phi} \\ \frac{1}{4}\left(\frac{\lambda}{\kappa}\right)^2 - \phi & \text{if } 2\sqrt{\phi} \leq \frac{\lambda}{\kappa} \leq 2 \\ 1 - \phi & \text{if } 2 < \frac{\lambda}{\kappa} \end{cases} \tag{13}$$

and

$$s^* = \begin{cases} \sqrt{\phi} & \text{if } \frac{\lambda}{\kappa} < 2\sqrt{\phi} \\ \frac{\lambda}{\kappa} & \text{if } 2\sqrt{\phi} \leq \frac{\lambda}{\kappa} \leq 2 \\ 1 & \text{if } 2 < \frac{\lambda}{\kappa}. \end{cases} \tag{14}$$

Proof. In order to obtain (12), use (9), (10), and (11). Note that the left-hand side of (12) is decreasing in g and converges to infinity as $g^* \to 0$. The right-hand side is strictly increasing in g. Thus, a balanced growth path exists and unique. ■

This theorem demonstrates that the balanced growth rate is determined by two key economic parameters: (i) the labor cost of private defense relative to innovation, κ/λ, and (ii) the strength of intellectual property laws in the South, ϕ. In what follows, we will investigate the roles of these parameters.

First, we investigate the effect of a reduction in the relative cost of private defense, κ/λ, or an increase in λ. Take the case of $\lambda < 2\sqrt{\phi}\kappa$ or $2\kappa < \lambda$. In this case, as (13) and (14) show, a change in λ does not affect either z^* or s^*. If $\lambda < 2\sqrt{\phi}\kappa$, $z^* = 0$, which implies that a change in λ does not affect g^*. If $2\kappa < \lambda$, $z^* = 1 - \phi$. Since equation (12) depends on z^*, a change in λ affects

g^*. Since the increase in λ leads to a decrease in z^*/λ in (12), an increase in λ raises g^*. Finally, take the case of $2\sqrt{\phi}\kappa \leq \lambda \leq 2\kappa$. On the one hand, an increase in λ raises z^*/λ, which makes resources more scarce in the North. Thus, through (12), this has a negative effect on g^*. On the other hand, the increase in s^* has two different effects. The first is to increase production within the North, which has a negative effect on innovation because it makes resources more scarce in the North. The second effect is to increase the expected value of an invention, which has a positive effect on innovation because it raises the incentive for innovation. These factors determine the relationship between λ and g^*. The next proposition provides a sufficient condition under which g^* is decreasing in λ.

Proposition 1 *Let $2\sqrt{\phi} \leq \lambda/\kappa \leq 2$. The cheaper the cost of private defense activities relative to innovation (i.e., the larger λ), the lower the balanced growth rate, g^*, if*

$$\sigma < 4/\left(2-\phi\right).$$

Moreover, a change in λ does not affect g^* if $2\sqrt{\phi} \geq \lambda/\kappa$ whereas an increase in λ raises g^* if $\lambda/\kappa \geq 2$.

Proof. If condition $\left(\frac{\lambda}{\kappa}\right)^2 (0.5\sigma - 1) < \phi\sigma$ holds, the right-hand side of (12) is globally increasing in λ for all $\lambda \in (0, +\infty)$. If $\sigma \leq 2$, this inequality necessarily holds. If $\sigma > 2$, the left-hand side of the inequality is an increasing function of λ/κ. Thus, it suffices to show that the inequality holds when λ/κ is equal to its upper bound, i.e., $\lambda/\kappa = 2$. This occurs if and only if $\sigma < 4/\left(2-\phi\right)$. Noting $4/\left(2-\phi\right) \geq 2$, this establishes the proposition. ■

Next, we examine the role of ϕ. Towards this end, we demonstrate that there is a cut-off value for ϕ, $\bar{\phi}$, such that the tightening of intellectual property laws in the South (an increase in ϕ) raises the growth rate, g^*, if ϕ is smaller than the cut-off, $\bar{\phi}$, and reduces g^* if ϕ is larger than $\bar{\phi}$. This implies that ϕ and g^* form an inverted U-shaped graph in the (ϕ, g^*) space.

First, take the case of $\phi \leq 0.25(\frac{\lambda}{\kappa})^2$. If $2 < \frac{\lambda}{\kappa}$, the middle expressions of (13) and (14) are void. Then, by the bottom expressions of (13) and (14), $z^* = 1 - \phi$ and $s^* = 1$. If $2 > \frac{\lambda}{\kappa}$, the bottom expressions of (13) and (14) are void. Then, by the middle expressions of (13) and (14), $z^* = 0.25\left(\frac{\lambda}{\kappa}\right)^2 - \phi$ and $s^* = \frac{\lambda}{\kappa}$. In either case, an increase in ϕ does not affect the survival rate of intellectual properties, s^*, but makes imitation more difficult, thereby letting R&D firms in the North to reduce their private defense activities,

$\partial z^*/\partial\phi = -1$. It may be demonstrated that this increases the labor input spent for innovation, resulting in an increase in balance growth rate, g^*.

Next, take the case of $\phi > 0.25\left(\frac{\lambda}{\kappa}\right)^2$. Then, by (13) and (14), $z^* = 0$ and $s^* = \sqrt{\phi}$. This implies that intellectual property laws in the South is so tight that R&D firms in the North have no incentive to spend resources on private defense, ($z^* = 0$). A further tightening of intellectual property laws in the South (or an increase in ϕ), however, raises the survival rate of intellectual properties, for $s^* = \sqrt{\phi}$. This slows down the dissemination of innovation from the North to the South and lowers g^*.

These findings can be summarized as follows:

Proposition 2 *Let $\bar{\phi} = 0.25\left(\frac{\lambda}{\kappa}\right)^2$. An inverted U-shaped relationship holds between the strength of intellectual property laws in the South, ϕ, and the balanced growth rate of technologies in the North, g^*. That is, g^* is increasing in $\phi < \bar{\phi}$ and decreasing in $\phi > \bar{\phi}$. The maximum balanced growth rate is achieved at $\bar{\phi}$.*

Helpman (1993) shows that, without the private defense of intellectual properties, the tightening of intellectual property laws in the South has a negative impact on the balanced growth rate in the North. Proposition 2 shows that, even in the presence of private defense activities, the same effect becomes predominant in the case in which intellectual property laws are sufficiently well developed in the South (or in the case of $\phi > \bar{\phi}$). In the case in which intellectual property laws are not sufficiently developed, the tightening of intellectual property laws in the South works to the contrary, thereby raising the balanced growth rate in the North.

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