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Economic Growth and Information Disclosure through Two IPR Protections: Patent and Trade Secret[*]

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Abstract

This paper analyzes the growth effect of strengthening patent protection to which trade secret is introduced as another protection method. In the model, innovators protect their inventions comprising many fractional parts by patent and trade secret. While trade secrets conceal the technological information in the short run, patents partially disclose the information to competitors. When the patent protection is strong, competitors can hardly use the technological information freely and it helps successful innovators earn higher profits. On the other hand, less disclosed information deteriorates the other firm's R&D productivity. The result shows that strengthening patent protection increases the growth rate when the leakage risk of trade secrets is high. However, when the risk is low, stronger patent protection hinders growth.

JEL Classification: O31, O34, L16

Keywords: Innovation, Patent, Trade Secret, Imitation, Disclosure Requirement in Patent Application.

1 Introduction

In the traditional view, strong intellectual property rights (IPRs) protection enhances economic growth because it secures innovator's profits and provides inventors with incentives to innovate. Although there is a trade-off between monopolistic distortion and economic growth (e.g., Nordhaus 1969), static distortion has been regarded as a necessary evil for dynamic gain. In the recent decades, enhancing IPR protection has been promoted largely by the OECD countries, especially after 1994, when the TRIPS Agreement was implemented.[1]

However, empirical studies do not necessarily show a positive relationship between economic growth and the strength of IPR protection.[2] For example, Falvey et al. (2006) showed that the effect of IPR on growth is positive in low- and high-income countries but not positive in middle-income countries. Chen and Puttitanun (2005) estimated the effect of IPR on GDP per capita in developing countries and showed a U-shaped relationship between them. Similarly, Horii and Iwaisako (2007) also pointed to the ambiguous relationship between the level of patent protection and the average per capita growth rate. In addition, some empirical studies show that stronger IPRs have a non-monotonic effect on R&D. For example, Allred and Park (2007) find a U-shaped relationship between firm-level R&D and the strength of patent rights in developed countries.

A patent holder can transmit private information to competitors even before the patent expires.[3] While the patent system is meant to protect the properties, during the patent prosecution process, applicants for a patent must disclose some technological information to the public in

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[1] Park (2008) created an index that represents the level of patent protection. The index is composed of five scores, some of which are duration of protection, patentable coverage, and enforcement mechanisms. Using this index, he showed that the strength of patent protection has increased over time globally.

[2] At this point, we may need to pay attention to time lag as one reason. Generally speaking, R&D projects take time to complete, especially for commercialization; therefore, the growth effect may not appear immediately after the policy change.

[3] For example, the detail of the technological information of numerous patent applications can be accessed freely on the Internet. The amount of access to the website of the Japan Patent Office (JPO) from China is very large, and experts note that the website is used for imitative activities in China.

return to receive protection. When the patent system requires a high degree of disclosure in the application, the disclosed information gives competitors clues that help them catch up and even innovate further. This disclosure actually causes some firms to avoid patenting their innovation. Cohen et al. (2002) reported that 46% of Japanese firms report "over disclosure" as the most important reason for not applying for a patent. In this paper, I defined the level of disclosure requirement in patent application as the strength of patent protection.

Trade secrets have an advantage over patents in that they do not disclose any information to competitors unless the secrets are leaked. In a questionnaire by Cohen et al. (2002), most U.S. firms respond that trade secrets are more effective than patents for appropriating benefit from innovation.[4] In addition, Cohen et al. (2000, p. 7) state that *"Different mechanisms may even be employed at the same time for a given innovation when an innovation is composed of separately protectable components or features."* Thus, to study IPR policies more realistically, we need to focus on the role of trade secrets as an alternative protection.

The model considers an economy in which innovators develop a good that contains many fractional parts. A successful innovator decides how many parts of the good are to be protected by patent, and the rest are maintained as trade secrets. Patents ensure a stable profit in the long run, but the period profit is relatively low because the patents disclose technological information to competitors. On the other hand, by keeping the information a secret, the patent holder can earn high period profit in the short run. However, if the secret leaks out to competitors, profits will drastically decrease because the innovation has not been patented. Some studies in industrial organization address the decision of whether to patent.[5] However, in DGE modeling, there are few studies in which two IPR protections and the patenting behavior are explicitly introduced.

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[4]Especially in the process innovation, both U.S. and Japanese firms depend on trade secrets rather than other protection methods.

[5]Anton and Yao (2004) established a model in which an innovator discretely decides whether to protect his innovation by patent or as a trade secret, as well as what aspects of the invention are the innovator wishes to disclose. Similarly, Ottoz and Cugno (2008) constructed a model in which an innovator can protect the innovation by a patent-secret mix. These studies focus on how innovation size and strength of protection change a firm's protection strategy, and do not include an analysis of how such a change affects the economy.

This paper investigates the growth effect of disclosure necessary for patent protection. In the model, disclosed information becomes the common knowledge and other firms can use it for the partial imitation and further innovation. Lowering disclosure requirement decreases the amount of the common knowledge, which has two opposite effects on economic growth. First, the reduction of the common knowledge increases profit because the productivity of competitive fringes becomes low. This profit increase naturally stimulates the incentives for innovation. However, because potential innovators cannot access much of the information, it increases their R&D costs and discourages innovation in the long run. When the leakage risk is sufficiently low, the former positive effect dominates the latter negative effect. As a result, lowering the disclosure requirement may accelerate economic growth. Interestingly, in the case of middle leakage risk, the relationship between the required disclosure level in the patent application and economic growth exhibits a U-shaped curve.

Although most studies have concentrated on analyzing the optimal patent policy, they have not yet reached a consensus on the optimal strength of IPR protection. In the context of industrial organization, Gilbert and Shapiro (1990) conclude that a patent system with infinite length and narrow breadth is desirable. On the other hand, Klemperer (1990) shows that a patent design with either very long or very short length is optimal. In DGE modeling, the pioneering work by Judd (1985) demonstrates that the optimal length of patent protection is infinite. However, Horowitz and Lai (1996) and Iwaisako and Futagami (2007) deem finite length to be optimal.

In addition, there are few studies in which trade secret is explicitly introduced. Some studies do not specify the protection method by treating the probability that costless imitation occurs as a level of IPR protection. In such a context, Horii and Iwaisako (2007) obtained an inverted U-shaped relationship between IPR protection level and growth rate. This specification is feasible for simplification and contributes to an analysis of the abstract effects of IPR protection.

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However, the result of such studies may be too generic to be employed as an actual IPR policy.

The main difference between the current study and the aforementioned literature is that I explicitly consider both IPR protection and endogenous "mixed protection" in the model. By studying this realistic situation, we can obtain a new implication of IPR protection and the role of information disclosure.

The rest of the paper is structured as follows. Section 2 briefly introduces the role of patents and trade secrets in the model. Section 3 develops an endogenous growth model that incorporates two IPR protections. We obtain the growth effect of two IPR protections numerically in section 4. Finally, section 5 concludes the paper.

2 Basic Setup of Patent and Trade Secret

First, this section briefly shows the role of two IPR protections by calculating the firm's profit. Suppose that there is only one good that comprises many fractional parts, and the good is produced by a monopolist. Let $\mu \in [0, 1]$ denote the percentage of "patented parts" in the good. Then, $1 - \mu$ indicates the portion of "secret parts." Although μ is exogenous here, we will derive it endogenously in the next section. For simplicity, I assume that the patent protection goes forever unless the firm pays the patent maintenance fee.

Patents are an imperfect form of protection because the firms must disclose the technological information of the innovation when they apply for the patent. Furthermore, this process enables imitators to access the information about the product's composition or the production method. I simply assume that a fraction of $\delta \in [0, 1]$ in the patented parts becomes common knowledge and that other firms can use the information without infringing the patent. We can regard δ as the requirement level of the patent disclosure in the patent application or the level of openness of the patent system. Therefore, a large δ indicates weak protection.

Similarly, the trade secret approach does not offer perfect protection because the secret leaks
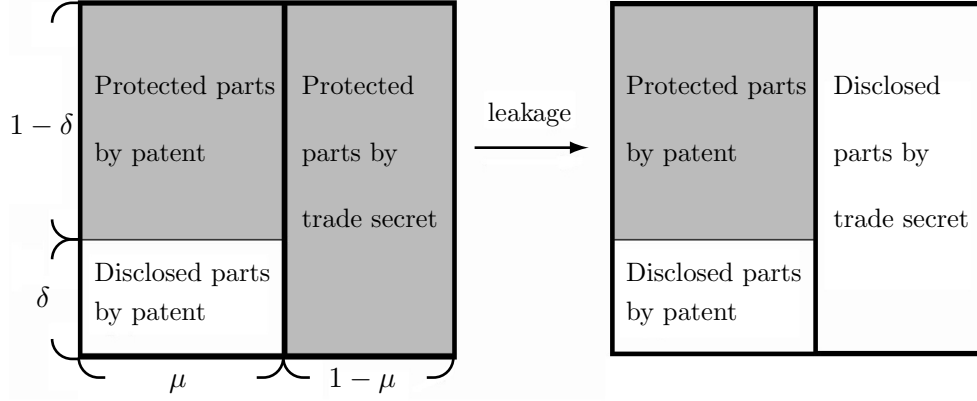
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Figure 1: The transition of protected parts of the innovation. The protected parts in each stage are represented by the shaded area. The left panel depicts the stage before the trade secrets are leaked out (stage-1), and the right panel shows the stage after leakage (stage-2).

out with a probability of ℓ. The firms can keep the trade secret as private information at first, but once the leakage occurs, all the secret parts of the good are disclosed. For convenience, we call the situation before (after) the leakage "stage-1 (stage-2)."

Fig 1 shows how the two ways of protection individually classify the innovation into protected parts and disclosed parts for each stage. The innovation is divided into patented parts μ (left side) and secret parts $1 - \mu$ (right side). In stage-1, the secret parts are perfectly protected, but the patented parts are partially protected due to the information disclosure by patent application. Thereby, the patented parts are bisected into protected parts and disclosed parts, as shown in the left panel of Fig 1. As a result, the protected parts of the innovation in stage-1 are all secret parts and partial patented parts. In stage-2, all the secret parts are disclosed and the protected parts are only the partial patented area, as depicted in the right panel of Fig 1.

I define $d_n(\mu)$ as the percentage of unprotected parts of the good in stage $n = 1, 2$. From Fig 1, $d_n(\mu)$ is evaluated as follows.

$$d_1(\mu) = \delta\mu, \tag{1}$$

$$d_2(\mu) = 1 - (1 - \delta)\mu. \tag{2}$$

The monopolist has a technological advantage against the imitators according to the amount of protected information. He can produce one good by employing one worker. On the other

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hand, imitators can produce $\chi_n \leq 1$ units of the same good with one unit of labor.[6] I assume that χ_n depends on d_n and specify χ_n as following the function of μ.

$$\chi_n(\mu) = \lambda^{-1} + (1 - \lambda^{-1})d_n(\mu), \ n = 1, 2. \tag{3}$$

λ^{-1} is the minimum value of χ_n, which is attained when no information is disclosed $(d_n = 0)$. We can check $\chi_1(\mu) = 1$ when $d_n(\mu) = 1$ and $\chi_1(\mu) = \lambda^{-1}$ when $d_n(\mu) = 0$ hold.[7] Because imitators can use additional information $(1 - \mu)$ after the leakage, the amount of information disclosure in both stages may be different $(d_1 \leq d_2)$. For this reason, $\chi_1(\mu) \leq \chi_2(\mu)$ holds, which implies the advantage in stage-1 is larger than 1 in stage-2 when $\mu < 1$.

In the market, the monopolist and the imitators are engaged in Bertrand competition and the monopolist employs the *limit-pricing* strategy. The unit production cost of the imitator in stage-n is $\chi_n^{-1}w$, and the unit cost of monopolists is w. Therefore, the monopolist can exclude the imitators from the market with a price $p = \chi_n^{-1}w$.

To derive the profit of the monopolist, I assume that the demand function is an inverse of the price, $x(t) = 1/p(t)$, and the total consumer expenditure equals 1.[8] Then, the monopolist's profit is

$$\begin{aligned} \pi_n &= p \cdot x - w \cdot x \\ &= 1 - w \cdot \frac{\chi_n}{w} \\ &= (1 - \lambda^{-1})(1 - d_n). \end{aligned}$$

Finally, we can calculate π_n in each stage as follows:

$$\pi_1(\mu) = \left(1 - \lambda^{-1}\right)(1 - \delta\mu) \quad \text{and} \tag{4}$$

$$\pi_2(\mu) = \left(1 - \lambda^{-1}\right)(1 - \delta)\mu. \tag{5}$$

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[6]We can also interpret χ_n as the cost disadvantage for imitators. When χ_n is very small, imitators must input a large number of workers for production. In contrast, imitators can perfectly copy in the case of $\chi_n = 1$.

[7]The case of $\delta = 0$ and $\mu = 1$ corresponds to Grossman and Helpman's model in which the technological advantage of the monopolist is λ^{-1}.

[8]In the full model, I will show that the assumption is endogenously obtained in the equilibrium. Here, we take the results in advance.
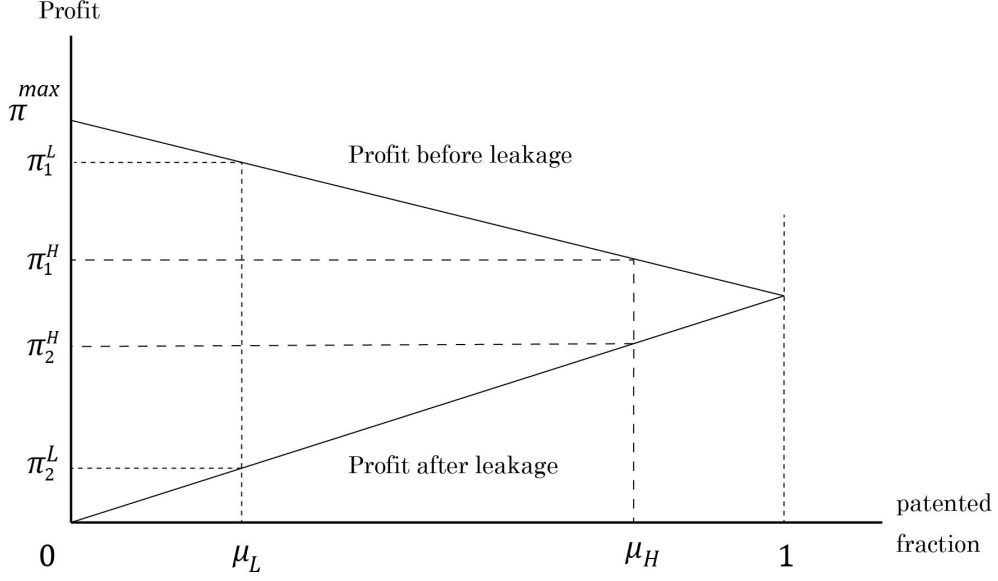
Figure 2: Patented fraction and the profit in each stage.

Fig 2 shows the profit curve for each stage. π_n is the linear function of μ and satisfies $\pi_1(1) = \pi_0(1)$ and $\pi_2(0) = 0$. The upper downward-sloping straight line represents the profit for stage-1 and the lower upward-sloping straight line is the profit for stage-2.

Here, there is a trade-off between π_1 and π_2. To see this briefly, consider the case that the innovator protects a small fraction of the innovation by patent (μ_L). Then, he can earn a relatively high profit before leakage (π_1^L) because most of the technological information is concealed from other firms. However, after the leakage occurs, he obtains a low profit (π_2^L) because the patented parts that still remain are relatively small. Next, we consider the case where the innovator patents a large fraction of the innovation (μ_H). Because the technological information about the patented parts is partially disclosed to other firms, he earns a relatively small profit in stage-1 (π_1^H). After the leakage, however, the reduction size of the profit is relatively small because the innovator does not overly depend on maintaining the trade secret. Therefore, he can still earn a relatively high profit in stage-2 (π_2^H).

3 The Rest of the Model

The model is an extension of Grossman and Helpman (1991), which is a quality-ladder model. There is a continuum of the sector indexed by $j \in [0, 1]$ and a monopolist in each sector. The monopolist can earn profit until a potential firm succeeds in an innovation in that sector. Because the quality of a new product is higher than the previous one, the incumbent is replaced by the new innovator. For a more detailed description of the model, see Grossman and Helpman (1991).

3.1 Households

The economy consists of L identical households and there is no population growth. Each household serves a unit of labor inelastically and gains a wage w in every period. They maximize intertemporal utility over an infinite horizon as follows:

$$U_t = \int_t^\infty e^{-\rho(\tau - t)} \ln C(\tau) d\tau, \tag{6}$$

where ρ is the subjective discount rate, and $C(\tau)$ is an index of consumption at time τ. The instantaneous utility is given by

$$\ln C(\tau) = \int_0^\theta \ln \left(\sum_{m=0}^{\tilde{m}_i} \lambda^m(i) x_{mt}(i) \right) di + \int_\theta^1 \ln \left(\sum_{m=0}^{\tilde{m}_j} \lambda^m(j) x_{mt}(j) \right) dj, \tag{7}$$

where $x_{mt}(i)$ is the consumption of the good whose quality is m in industry i at time t, and θ is the number of the industries from whom the monopolist has shielded the trade secret (the situation in stage-1). For convenience, we call such industries "sector-1." Then, $1 - \theta$ is the number of the industries to whom the monopolist's trade secret has been disclosed; we call these industries "sector-2."

The quality of each good is represented as an integer m power of $\lambda > 1$, which means that the quality of the new good is λ times as high as the previous one. In industry i, there are $\tilde{m}_i$

types of goods, and the quality of the latest good is $\lambda^{\tilde{m}_i}$. In the equilibrium, households buy only the good of the highest quality in each sector because of limit-pricing.

Under the logarithmic utility function, households equally spend their budget across the industries. Therefore, the demand of a good in the industry i is $x_{\tilde{m}_i}(t) = E/p_{\tilde{m}_i}(t)$, where E is expenditure and $p_{\tilde{m}_i}$ is the price of the good whose quality is $\tilde{m}_i$.

In this setting, the ideal price index associated with the consumption index C is

$$P = \exp\left[\int_0^\theta \ln\left(\frac{p_{\tilde{m}_i}}{\lambda^{\tilde{m}_i}}\right) di + \int_\theta^1 \ln\left(\frac{p_{\tilde{m}_j}}{\lambda^{\tilde{m}_j}}\right) dj\right]. \tag{8}$$

Given the aggregate price index, households spend to maximize their intertemporal utility. From the result of the maximization, household's optimal time path of spending is represented by $\dot{E}/E = r - \rho$. By using aggregate expenditure as the *numéraire* according to Grossman and Helpman (1991), we get $E = 1$ and $r = \rho$.

3.2 Firms

The time schedule in an industry is as follows. At first, a successful innovator chooses optimal mixed protection between patent and trade secret. Then, he produces goods and earns profit in stage-1 until innovation occurs in the industry with a probability of z_1. In addition, the secret parts of the innovation leak out with a constant probability ℓ in stage-1. After that, the incumbent moves to stage-2 and his profit decreases due to the information disclosure of the secret parts. Furthermore, once another firm succeeds in its R&D with an innovation rate z_2, it replaces the incumbent and emerges as the new incumbent.

I assume that the patent cost is a maintenance fee for simplicity and that the incumbents must pay $c(\mu) = \gamma\mu^2/2$ in every period, where $\gamma > 0$.[9] To analyze the role of trade secret, I

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[9]While the specification of convex patent cost enables us to obtain an interior solution, most fees (e.g., filing fees) may be proportional to the number of patents. However, the patent cost in the model includes not only application cost but also other costs. For example, to be granted a patent of an invention of which it is difficult to determine the non-obvious aspects (e.g., Program code), innovators need to pay additional costs for the patent-issuing. Suppose a good comprises many parts and each part has a peculiar difficulty in being granted the patent. At first, innovators will apply first for patents of the easiest parts, but eventually they will be required to pay additional costs to file subsequent patents.

assume that γ is not so small and therefore the optimal μ is less than 1 in the equilibrium. Their period payoff is the profit obtained in section 2 minus the patent cost. An incumbent decides μ for maximizing the value of innovation V_1, defined as a total expected payoff after the innovation occurs. First, we calculate V_2, which is the expected sum of the payoff after the trade secret leakage.

$$
\begin{aligned}
V_2 &= \int_t^\infty e^{-(r+z_2)s} \left[\pi_2(\mu) - c(\mu)\right] ds. \\
&= \frac{\pi_2(\mu) - c(\mu)}{r + z_2}.
\end{aligned}
\tag{9}
$$

Then, from a no-arbitrage condition, V_1 is derived as follows:

$$
rV_1 = \pi_1(\mu^*) - c(\mu^*) + \ell\left(V_2 - V_1\right) - z_1 V_1
$$

$$
\Leftrightarrow \quad V_1 = \frac{\pi_1(\mu^*) - c(\mu^*) + \ell\left[\pi_2(\mu^*) - c(\mu^*)\right]/(r + z_2)}{r + \ell + z_1}.
\tag{10}
$$

Each incumbent chooses his μ to maximize V_1 with a given z. From the first-order condition, we obtain an optimal μ as follows:

$$
\mu^*(z_2) = \begin{cases}
\gamma^{-1}\left(1 - \lambda^{-1}\right)\left(\frac{\ell}{r+\ell+z_2} - \delta\right) & \text{when } z_2 < \ell/\delta - r - \ell \\
0 \text{ when } z_2 \geq \ell/\delta - r - \ell.
\end{cases}
\tag{11}
$$

3.3 R&D sector

In the economy, all innovations stem from the R&D activities by potential firms.[10] The preceding R&D cost is covered by issuing equities whose value is equal to V_1.

The blueprints are invented according to the Poisson process so that the success probability in any time interval dt is $z_n dt = [L_R \Theta_n / A_n(\mu)]dt$, where L_R is the number of researchers, $\Theta_n/A_n(\mu)$ indicates the R&D productivity, $\Theta_1 = \theta$, and $\Theta_2 = 1 - \theta$. I assume that R&D becomes

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[10]This is called "allow effect" or "replacement effect." All incumbents in sector-1 have no incentive to innovate by paying some cost because they cannot increase their profit through the new innovation. The monopolists in sector-2 can raise their profit by successful innovation, although the incentive to innovate is lower than the incentive of the potential firms because they have zero-profit now and because the R&D technology is a constant return here. Therefore, all researchers are employed in the potential firms.

more efficient when the number of targeted sectors Θ_n is higher.[11] In addition, in this model, potential firms can obtain some clues for further innovation from the disclosed information. I specify $A_n(\mu)$, which indicates R&D inefficiency, as the following decreasing function of d_n.

$$A_n(\mu) = \bar{A} - d_n, \tag{12}$$

where $\bar{A}$ is a positive parameter.

3.4 Free Entry

A successful innovator earns expected payoff V_1. On the other hand, the innovator must pay R&D cost $wA_n(\mu)/\Theta_n$ for innovation in sector-n. Therefore, free entry into R&D in each sector requires that

$$w\frac{A_1(\mu)}{\theta} \geq V_1, \text{ equality holds whenever } z_1 > 0. \tag{13}$$

$$w\frac{A_2(\mu)}{1 - \theta} \geq V_1, \text{ equality holds whenever } z_2 > 0. \tag{14}$$

3.5 Labor Market

In the economy, the labor supply L is allocated between production and R&D; therefore, the labor market clearing condition is

$$L = \theta\frac{\chi_1(\mu)}{w} + (1 - \theta)\frac{\chi_2(\mu)}{w} + A_1(\mu) \cdot z_1 + A_2(\mu) \cdot z_2. \tag{15}$$

3.6 Equilibrium

At first, we derive the condition that the fractions of sector-1 and sector-2 are constant over time. A monopolist in sector-1 moves into sector-2 with a constant probability ℓ. On the other hand, a firm in sector-2 is replaced by a new incumbent in sector-1 with a probability z_2. Then,

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[11]This spillover can be interpreted as follows. Each industry potentially has a different R&D difficulty and potential firms may find it easy to discover a suitable industry in which to innovate when the number of the "target" is large.

the instantaneous change of θ is presented as $\dot{\theta} = (1-\theta)z_2 - \ell\theta$. Therefore, in the steady state, the following equation holds:

$$\theta = \frac{z_2}{z_2 + \ell}. \tag{16}$$

There are two types of equilibrium in the model.[12] The first case is that all R&D concentrate in sector-2, $z_1 = 0$ and $z_2 > 0$. Recall that $A_1 \geq A_2$ necessarily holds. If the initial number of sector-2 is sufficiently large, potential firms target only the industries in sector-2 because the R&D productivity is high. Although larger z_2 decreases the $(1-\theta)$, the equilibrium of this case becomes stable when ℓ is sufficiently large. In this case, next equation holds in the equilibrium:

$$\frac{A_1}{\theta} > \frac{A_2}{1-\theta}. \tag{17}$$

The second case is that innovation simultaneously occurs in two sectors, $z_1 > 0$ and $z_2 > 0$. In this case, the R&D productivity across the sector is the same, and innovators are indifferent with regard to the sector. Therefore, the next equation holds:

$$\frac{A_1}{\theta} = \frac{A_2}{1-\theta}. \tag{18}$$

Once the long-run equilibrium is determined, we can calculate the growth rate of the consumption index C as below:

$$g^* = [\theta z_1 + (1-\theta)z_2]\ln\lambda. \tag{19}$$

4 Simulation

This section examines the growth effect of the disclosure requirement of the patent system. To discuss the effect, I numerically calculate the relationship between δ and the growth rate under different ℓ.

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[12]The model does not have *third* case in which $z_1 > 0$ and $z_2 = 0$ are satisfied. In this case, $A_1/\theta < A_2/(1-\theta)$ initially holds. However, some industries in sector-1 continuously move to sector-2 due to information leakage, and θ gradually decreases until $A_1/\theta = A_2/(1-\theta)$ holds.
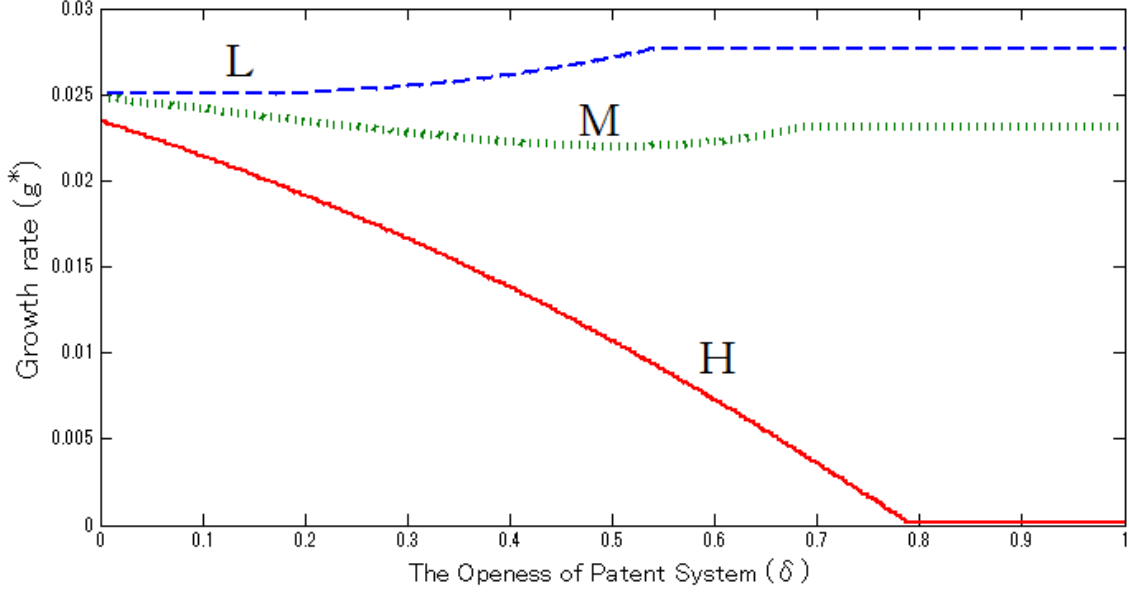
Figure 3: Growth rate and the openness of the patent system (δ). The upper curve "L" corresponds to the case of $\ell = 0.35$. The middle curve "M" is the case of $\ell = 0.45$. The lower curve "H" is the case of $\ell = 0.8$. These graphs indicate that the growth effect is ambiguous and depends on the leakage probability.

4.1 First case: $z_1 = 0$ and $z_2 > 0$

The simulation uses the following parameters: $L = 4$, $\lambda = 1.2$, $\rho = 0.03$, $\bar{A} = 2$, and $\gamma = 1/4$.

For a sample of the leakage probability, the simulation uses $\ell = 0.35$, $\ell = 0.45$, $\ell = 0.8$.

Fig 3 shows three different patterns of the growth effect. In Case L ($\ell = 0.35$), weak patent protection (higher δ) enhances growth. In contrast, in Case H ($\ell = 0.8$), larger δ has a negative impact on growth in an opposite direction. In Case M ($\ell = 0.45$), the relationship exhibits U-shape and the growth effect depends on the initial δ.

Interpretation

The influence on g due to the weakening patent policy ($\delta \uparrow$) can be decomposed into the effects on $(1 - \theta)$ and z_2. However, as shown in Panel (a) of Fig 4, the relationship between innovation rate z_2 and δ determines the growth effect shown in Fig 3. Therefore, to interpret the result, we only have to focus on the impact of δ on z_2.
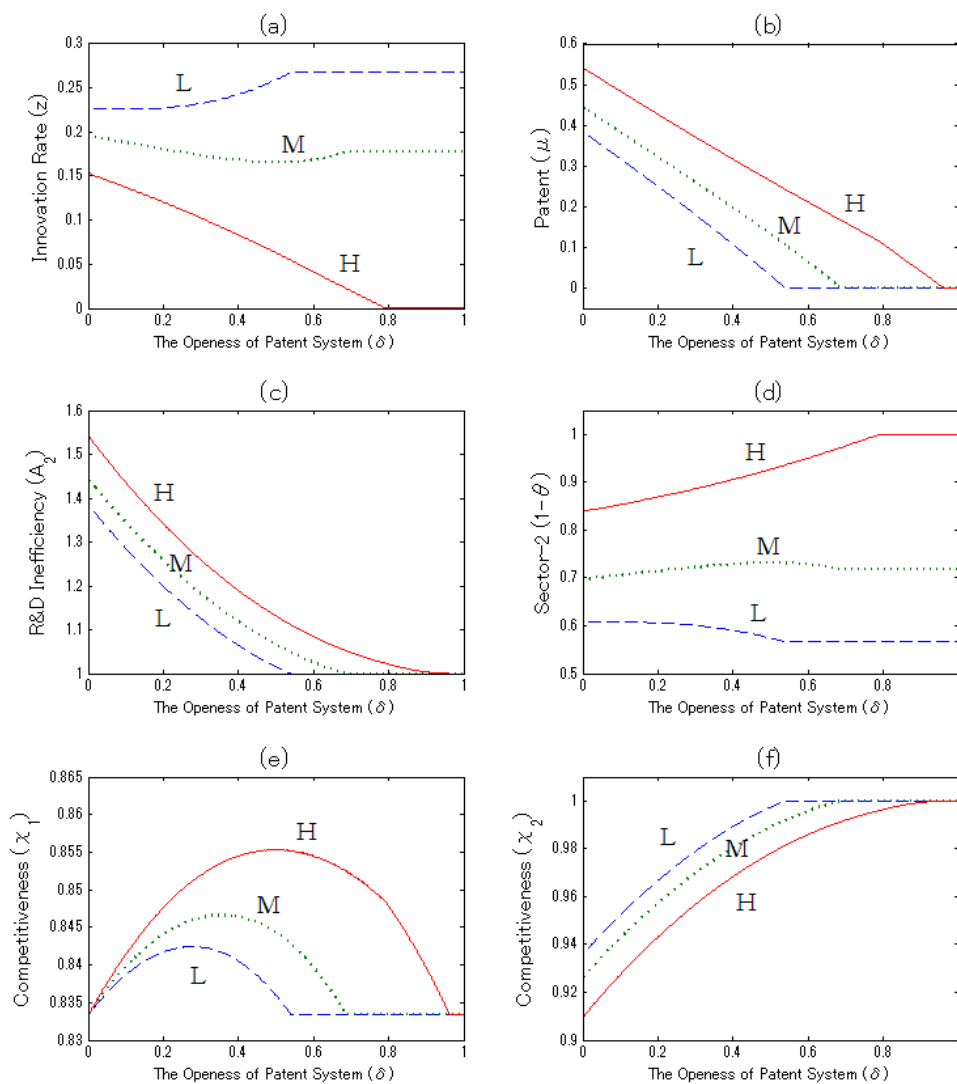
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Figure 4: Other variables and the openness of the patent system (δ).
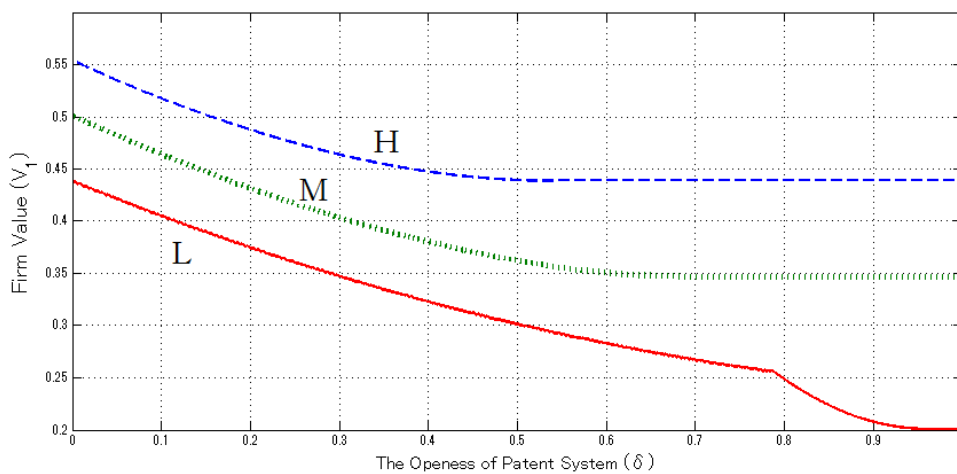

Figure 5: Firm value and the openness of the patent system (δ).

Suppose that the government adapts a stronger patent policy ($\delta \downarrow$). This policy has two opposite effects on the incentive of innovators. First, strong patent protection increases the firm value (V_1), as shown in Fig 5. When δ is low, competitive fringes have only little information of the inventions and then the cost advantage of the monopolists becomes high. Panel (f) of Fig 4 indicates that small δ necessarily decreases the productivity of competitive fringes in sector-2. Then, monopolists earn high profit because they can charge a high price. This effect on V_1 will stimulate the incentive of innovation. However, the second effect has a negative impact on innovation. When potential firms obtain only little information, the R&D inefficiency goes up as depicted in Panel (c) of Fig 4. As a result, the entire impact on innovation is determined by these opposite effects. For convenience, I call these "**cost advantage effect**" and "**R&D inefficiency effect**", respectively.

In Case H, the lowering disclosure in patent system ($\delta \downarrow$) has a positive effect on the growth rate. In this case, the cost advantage effect is relatively strong and dominates the R&D inefficiency effect. When ℓ is high, incumbents protect many parts of the invention by patent because trade secret is a relatively weak protection strategy. Then, the incumbent can conceal a great deal of information involved with the invention when the government decreases the disclosure requirement. This means the firm value is drastically increased by lowering δ, as shown in Fig 5.

In Case L, as illustrated in Fig 4, the lowering disclosure in patent system ($\delta \downarrow$) has a negative effect on the innovation rate. In this case, conversely, Panels (e) and (f) of Fig 4 show that small δ does not increase the monopolist's cost advantage a great deal. When ℓ is relatively low, innovators protect many parts of the inventions by trade secret. Therefore, the additional amount of the protected parts by strengthening patent protection ($\delta \downarrow$) is limited. Fig 6 briefly illustrates this mechanism.

In Case M, the policy has an ambiguous impact on the innovation rate. We can consider the

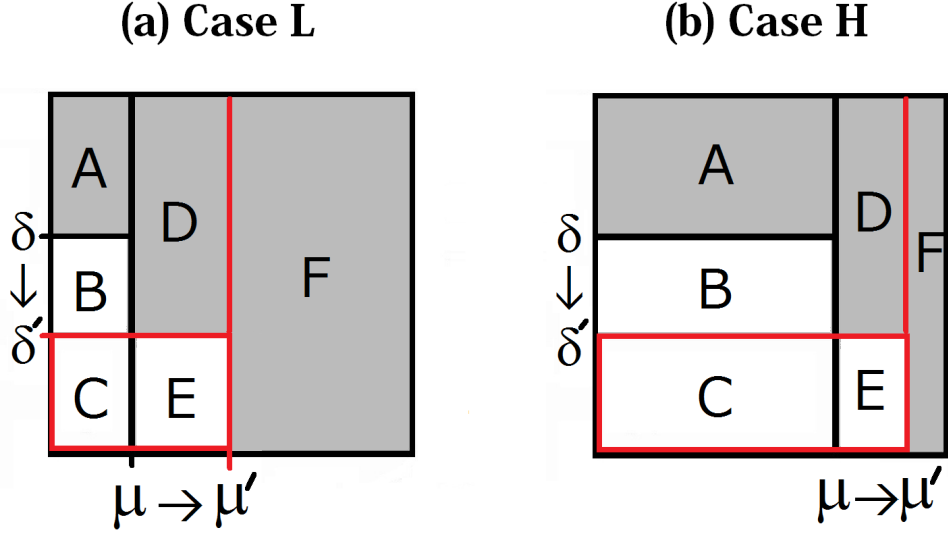**(a) Case L**   **(b) Case H**

Figure 6: Protected area and unprotected area in stage-1. Initial patented parts are regions A, B, and C, and secret parts are regions D, E, and F. Suppose that the government increases the strength of patent protection ($\delta \to \delta'$). Then, a new monopolist increases the fraction of patented parts ($\mu \to \mu'$). In this case, the additional amount of protected parts is represented by ($B - E$). Clearly, the amount is relatively high when the initial μ is large.

result by using the same interpretation. In this case, the cost advantage effect offsets the R&D inefficiency effect.

As a result, the size of the impact of strengthening patent protection on firm value depends on the firm's protection strategy and the optimal protection strategy is affected by the leakage rate.

4.2 Second case: $z_1 > 0$ and $z_2 > 0$

In this case, unlike the first case, innovation occurs in sector-1 and $\theta = A_1/(A_1 + A_2)$ holds. By using this equation and (16), we can obtain z_2 in the steady state. After that, from (1)-(5) and (10)-(15), we can also solve z_1 in the steady state.

The simulation of this case uses the following parameters: $L = 4$, $\lambda = 1.2$, $\rho = 0.03$, $\bar{A} = 2$, and $\gamma = 1/10$. As discussed above, when ℓ is sufficiently small the equilibrium of this case can be attained. Therefore, the numerical analysis uses $\ell = 0.02$, $\ell = 0.05$, and $\ell = 0.18$.

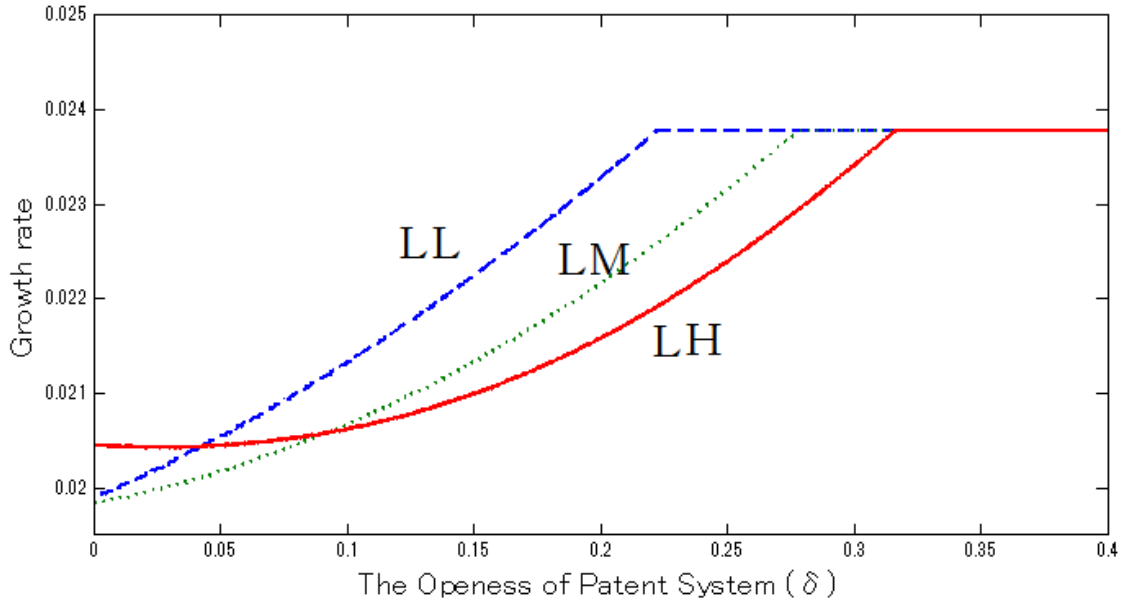The growth effect is shown in Fig.7. A lower δ primarily decreases the growth rate and the

Figure 7: Growth rate and the openness of the patent system (δ). The upper curve "LL" corresponds to the case of $\ell = 0.02$. The middle curve "LM" is the case of $\ell = 0.05$. The lower curve "LH" is the case of $\ell = 0.18$.

result is similar to the Case L in the first case. For the same reason in first case, strong patent protection discourages the innovation in sector-2. As represented in Fig 8, the curve which shows the relationship between z_2 and δ is upward-sloping in three cases. This negative impact on z_2 directly affect the growth rate in this case.

However, the effect of lowering δ on z_1 is ambiguous. Especially, Panel (b) and (c) of Fig 8 show a weak U-shape relationship between them. What causes the difference of the effect on innovation rate between sector-1 and sector-2? To consider this, let us look at Panels (c) and (d) of Fig 9. In sector-2, the R&D inefficiency drastically increases by lowering δ. On the other hand, the size of the negative impact of the R&D productivity in sector-1 is relatively small, as shown in the Panel (c). Recall that the additional amount of protected information becomes small when ℓ is sufficiently low as discussed in Fig 6. Although lowering the disclosure requirement of a patent certainly increases the protected parts per patented part, it also induces innovators to increase the fraction of patent protection. Because the latter effect works to offset the former, the R&D inefficiency effect is mitigated. As a result, the negative impact on the

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growth rate is also mitigated by the increase of z_1.

In addition, Panels (b) and (c) of Fig 8 also show that the sector in which innovative activity mainly concentrates is different between Case LM and Case LH. In Case LM, many potential firms engage in R&D in sector-1. When ℓ is sufficiently small, the number of sector-1 is relatively large, which stimulates innovation in sector-1. Conversely, in Case LH, the number of sector-1 is relatively small, which lowers R&D productivity in sector-1; therefore, $z_2 > z_1$ holds.

5 Conclusion

I extended the quality-ladder model of endogenous growth by considering two IPR protections and a choice problem between them. This model defined the strength of patent protection as the level of disclosure requirements in patent applications. The results showed that the growth effect of strengthening patent protection may discourage the growth rate.

When the disclosure level of the patent is small, it reduces the common knowledge because monopolists can conceal a great deal of information involved with the invention through the patent process. This concealment increases the cost advantage against competitive fringes and enables monopolists to obtain higher profit. As a result, it stimulates the incentive to innovate by increasing firm value. However, when innovators cannot use disclosed information for R&D due to the strong protection, R&D activity becomes inefficient. Therefore, lower common knowledge negatively affects the R&D productivity, and this effect discourages innovation. In particular, the latter negative effect is strong when the leakage probability is sufficiently small, and the growth effect of the policy becomes negative. In other words, when trade secret is a relatively strong protection strategy for innovators, strengthening patent protection is harmful for economic growth. When the leakage probability is sufficiently large and monopolists mainly protect their inventions by patent, strong patent protection conversely enhances the growth because the former positive effect is relatively strong. The results indicated that policy makers
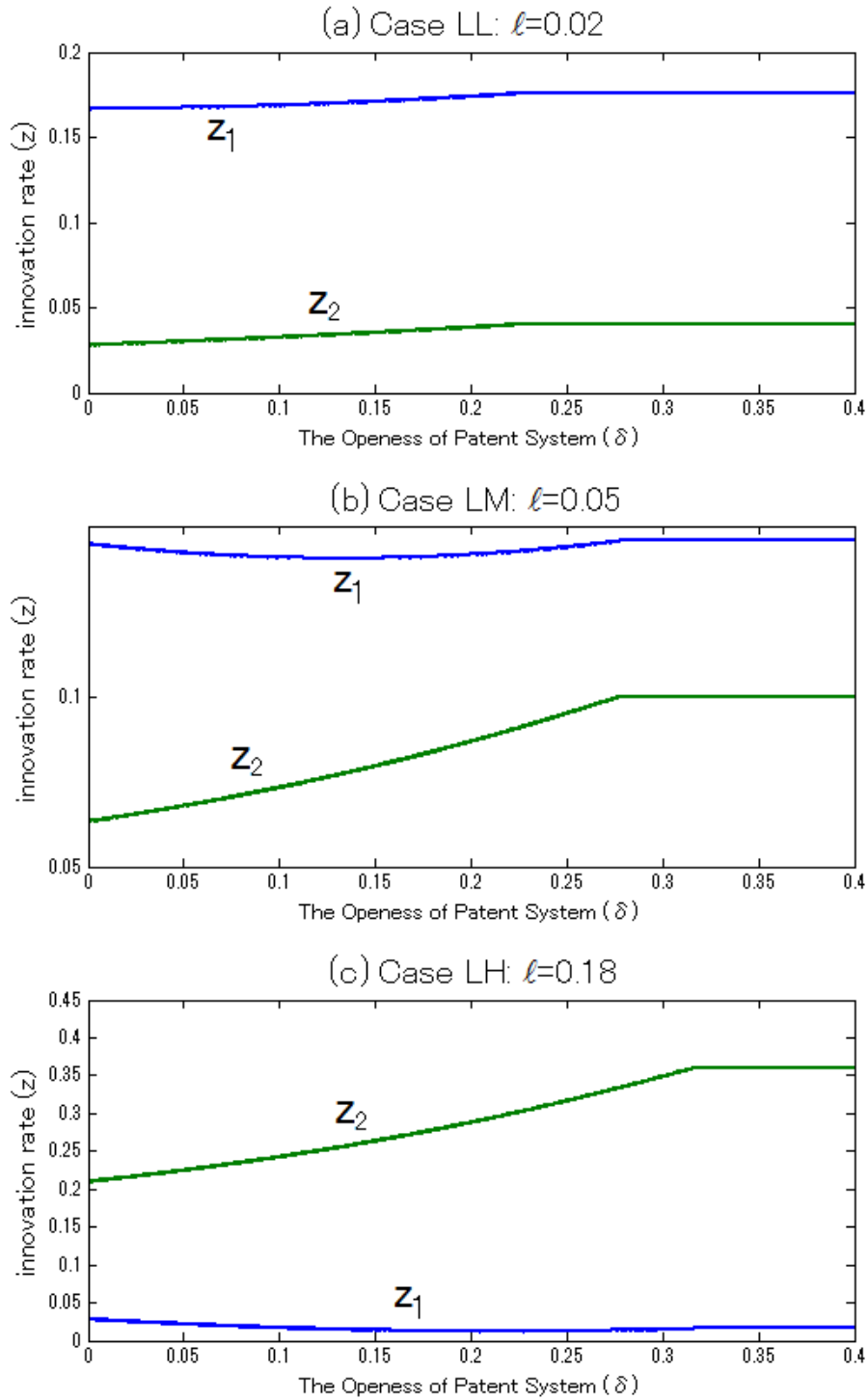
Figure 8: Innovation rates (z_1 and z_2) and the openness of the patent system (δ). The upper curve "LL" corresponds to the case of $\ell = 0.02$. The middle curve "LM" is the case of $\ell = 0.05$. The lower curve "LH" is the case of $\ell = 0.18$.
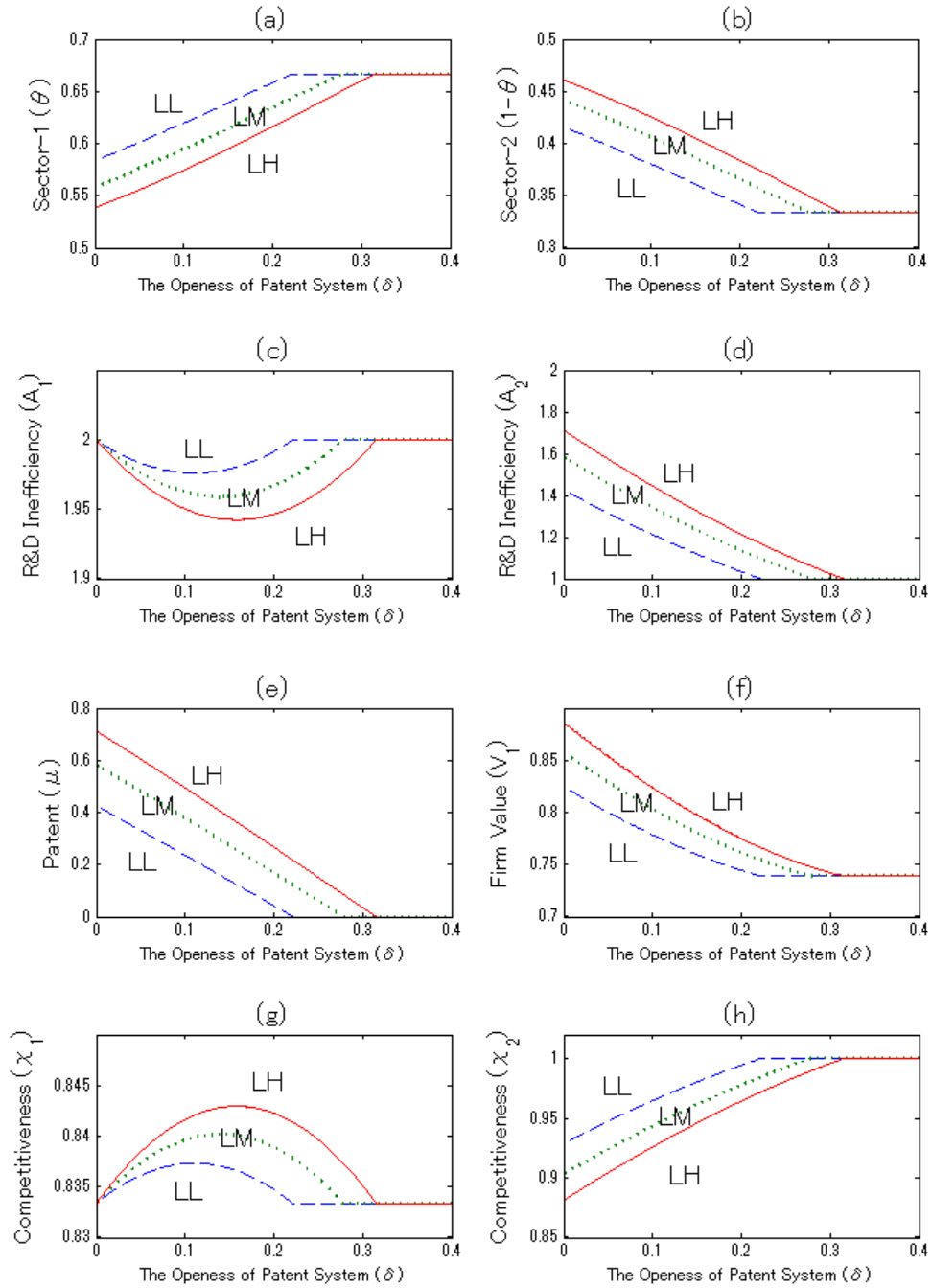
Figure 9: Other variables and the openness of the patent system (δ).

have to pay attention to the relative importance of patent protection for actual firms. In addition, the relationship between growth rate and patent strength are represented by a U-shaped curve under a middle leakage probability. This result has been empirically demonstrated (e.g., Chen and Puttitanun (2005)). In this case, policy maker should consider the current amount of disclosure required for patent protection.

In this paper, the leakage probability is regarded as an exogenous parameter. As an extension, we can consider the case where the probability is endogenously determined. For example, it does not seem very unlikely that the probability depends on the amount of trade secrets. If a firm has many trade secrets, it may be difficult for a firm to secure them all. Otherwise, using the leakage mechanism as a means to spy or reverse engineer an innovation can be one way to endogenize the leakage probability. However, regardless of the extension we consider, the model presented in this paper may serve as a starting point for the introduction of two IPR protections in a DGE model.

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