Who should Own Rights of Service Invention, Employees or Firms? [*]

Kyota Eguchi[**]

The University of Tsukuba
Institute of Policy and Planning Sciences

and

Kenichi Kuwashima[***]

The University of Tsukuba
Graduate School of Business Sciences

November 2003

---

[*] JEL Classification Numbers: K11, K12. This paper was represented in the 2003 annual meeting of the Japanese Economic Association at Meiji University.

[**] Correspondence: Kyota Eguchi, Lecturer, The University of Tsukuba, Institute of Policy and Planning Sciences, 1-1-1, Tennou-dai, Tsukuba, Ibaragi 305-8573, Japan. Phone & Fax: +81-29-853-5375.
e-mail: eguchi@sk.tsukuba.ac.jp

[***] Correspondence: Kenichi Kuwashima, Associate Professor, The University of Tsukuba, Graduate School of Business Sciences, 3-29-1, Otsuka, Bunkyo-ku, Tokyo 112-0012, Japan. Phone: +81-3-3942-6894 Fax: +81-3-3942-6829.
e-mail: kuwa@gssm.otsuka.tsukuba.ac.jp

Who should Own Rights of Service Invention, Employees or Firms?

Abstract

Who should own patent rights of new technologies discovered in the workplaces, firms or researchers? We use a multitask moral hazard model to consider the effect of ownership and regulations on service invention to social welfare. When employees own all rights of invention, they face excess incentive schemes, and thus inefficient risk sharing is realized. Moreover, employees are willing to pay much attention into what they like. Employees' ownership leads to distortion of their behavior. In contrast, in the case of firms' ownership, these distortions disappear, and thereby it is desirable that all rights of invention belong to firms. On the other hand, when the value of new technologies is difficult to measure, it can be better that rights of them belong to employees.

JEL Classification Numbers: K11, K12

1. Introduction

Firms devote much resource into R&D activities and employ researchers for invention. Employed researchers use the firms' resources like funds, items, and technologies to invent new technologies. Invention of new technologies by employed researchers who are hired for invention is called service invention. Firms' resources and employees' idea and efforts are necessary for service invention, however, there is a problem. Who should own the patent rights of new technologies, firms or researchers? We consider the effect of ownership and regulations on service invention to social welfare in this paper.

Recently, in Japan, some employed researchers who developed new technologies in their firms sue their firms for damages. They request the firms to provide much amount of payment. Employed researchers often complain of the firms' policy on compensation of service invention. In Japan, as a rule, patent rights of new technologies belong to employees in the case of service invention. Even when firms and employees make contracts that patent rights of new technologies developed in the firms belong to the firms, the firms must provide reasonable consideration as compensation of service invention to the employees. Even if firms and employees specify in the contracts that firms do not have to pay anything on service invention, the contracts like these are not accepted in court. When employees go to trial and request firms to provide reasonable consideration, firms must pay it after invention. This is a forcible provision in patent law in Japan. The forcible provision on service invention implies that the right of new technologies belongs to employees.

The matter on the forcible provision on service invention leads to annoyance in the actual business world. Recently, professor Shuji Nakamura in the University of California Santa Barbara sues his primary company Nichia Corporation and insists that the ownership of the patent of Blue LED (light-emitting diode) should belong to himself and he has the right to receive reasonable consideration as compensation of invention of Blue LED even if the ownership belongs to Nichia Corporation. Blue LED is useful technology for many industries and yields huge profit of thousands or hundreds billion yen.[1]

---

[1] There are the light's three primary colors: red, green, and blue. Since Red and Green LED had been developed previously, many researchers had tried to develop the last color, Blue LED. Professor Isamu Akasaki in Meijyo University first succeeded in the development of Blue LED and Professor Nakamura improved the quality of Blue LED. Success of the development of Blue LED

Professor Nakamura succeeded in the development of the Blue LED when he was employed by Nichia corporation. Professor Nakamura insists that all rights of Blue LED belong to himself and that the consideration he actually got was very small. A lot of attention is paid to professor Nakamura's trial and we observe different views on who should own rights of new technologies in service invention. Some journalists indicate that firms must provide much consideration as compensation of service invention because wage of engineers and researchers is comparatively lower than that of white collar workers. Other law researchers declare that employees should be protected since they are weaker than firms, and thus they insist that ownership of rights of service invention should belong to employees. On the other hand, firm managers state not only that employees are sufficiently compensated from the viewpoint of increase of wage and promotion but also that paper work to deal with service invention increases firms' costs. Hence, they require the Japanese patent law to be amended to delete the forcible provision on service invention and insist that firms and employees should be able to make contracts on service invention. This is a hot issue in Japan.

In Germany and Japan, matters on service invention are specified in the patent law. In Japan, when matters on service invention are not specified in contracts between firms and employees, the right on the new technologies discovered in the workshops belongs to employees. In this situation, firms can get non-exclusive licenses: the firms can free use the new technologies discovered in the workplaces without paying the license fees to the employees who are the owners of the patents. The employees can make license contracts on the new technologies with other individuals and firms to get license fees. As we mention later, this is similar to the case of shop right invention in the United States. On the other hand, when it is specified in the contracts that the rights on new technologies is transferred to firms, the firms must provide reasonable consideration to the employees. The amount of reasonable consideration as compensation of the invention depends on the value of the invention. The amount on reasonable consideration of the invention is determined after success of the invention. If new technologies lead to high profit, the reasonable consideration is high. The firms can use the new technologies free and make license contracts on them with other firms to get license fees: exclusive licenses on the technologies are granted to firms. The employees cannot make license contracts with other firms in this situation because the

---

means that we complete the light's three primary colors and can use them for application in various fields ('Weekly Diamond' ('Syukan Diamond' in Japanese) pp.84-87 June 23, 2001).

right of new technologies is transferred to the firms, though, they receive reasonable consideration as compensation of invention. This is the Japanese rule: ownership of new technologies as service invention belongs to employees. When ownership is transferred to firms, employees have the right to receive reasonable consideration. According to Takeda (2002), German system on service invention is similar to Japanese one.

Foster and Shook (1989) mention that, in the United States, it is occasionally specified in employment contracts between firms and researchers on who owns patent rights on new technologies as service invention. When matters on service invention are not sufficiently specified in employment contracts, determinant on ownership of new technologies depends on characteristics of employment. If workers are hired for invention, new technologies are regarded as service invention and the rights of them belong to the firms. Firms get all rights of the technologies. Unless it is specified in the contracts that firms provide additional payment on the invention, the firms do not have to give reasonable consideration on the invention. This is contrary to Japan. In Japan, as we stated above, all rights of service invention belong to employees who are hired for invention. If rights of invention are transferred to firms, the firm must provide reasonable consideration to employees. They cannot make contracts on service invention in Japan, in other words, there is the forcible provision on service invention in patent law.

On the other hand, in the U.S., if workers are not hired for invention but succeed in developing new technologies by using firms' resources, the workers get patent rights of the new technologies, however, the firms get the non-exclusive license on them for free. Although the firms do not have the exclusive license, the firms use the new technologies in the firms' production and activities for free. This case is called shop right invention.

We summarize the difference of rules of patent rights in table 1. In the U.S., firms and employees can make contracts on invention in the workplaces. Even if they do not make contracts on invention, firms own all rights of invention when employees are hired for invention. Employees have rights of invention only when they are not hired for invention and they do not specify in the contracts that rights of invention belong to the firms. In contrast, as we mentioned, rights of invention discovered in the workplaces belong to employees in Japan.

In the U.K., there is the discipline that patent rights of new technologies as service invention belong to the firms. Compared with Japan and Germany, the U.S. and

the U.K. are the countries where rights on service invention belong to firms.[2] Ohba (2002) raises many countries that have the patent policy on service invention similar to the U.S., for example, Australia, New Zealand, Canada, Denmark, Finland, Sweden, and Switzerland.

We consider the case that employed researchers develop new technologies as service invention in the workplaces. There are two ways that firms earn profit from new technologies by. One way is that the incumbent firms can use new technologies for their production and activities by themselves. This is a kind of specific use of new technologies. The incumbent firms make profit from the characteristic of the new technologies that they can use for their activities by themselves. We call the characteristic the (firm or industry) specific characteristic. The other way is that the firms get license fees by making license contracts with other firms. There is the other characteristic that the incumbent firms cannot or will not use new technologies by themselves because they do not know how to use it or the cost to use is huge. When other firms can use the characteristic, the incumbent firms make license contracts with the other ones to get license fees. This characteristic is called the non-specific characteristic in this paper.

We can raise the pharmaceutical industry as an example of the non-specific characteristic of technologies. Pharmaceutical firms including global Mega-Pharmas rarely have all kinds of products for dozens of therapeutic area. They strategically focus on some therapeutic areas for their business scope. In the pharmaceutical R&D processes, researchers happen to discover new chemical compounds (origins of new drugs) different from their original targets. These new discoveries do not necessarily belong to the business areas of the incumbent firms. In the development process, various resources of the firms, for instance, special and professional knowledge specific for the therapeutic area and the networks with hospitals and doctors, are essential to implement commercialization of research achievements and product merchandising. However, the incumbent firms are unlikely to have sufficient resources and know-how to use new discoveries by themselves when new discoveries are outside of their business areas. In this situation, it is observed that the incumbent firms make license contracts on them with other firms.

Even if ownership of new technologies belongs to employees, as we have indicated, the incumbent firms have free non-exclusive license. This is the Japanese

[2] Recently, according to Takeda (2002), there is the trend that firms provide consideration as compensation of invention to employees in the U.K. and U.S., especially when the impact of invention is big. We need to observe the change of the trend carefully.

case and the case of the shop right invention in the U.S. Hence, the incumbent firm gets profit from the specific characteristic of the new technologies because they can use the new technologies for their production and activities. However, the incumbent firms cannot make license contracts with other firms, and thus the firms do not get any profit from the non-specific characteristic of the new technologies. In this situation, employees who are the owners of the new technologies can make license contracts and get profits. On the other hand, when the firms own all rights of new technologies, the firms get profit from both the specific and the non-specific characteristics.

We consider two cases: the firm's ownership case and the employee's one (table 2). When firms own rights of the new technologies, firms do not provide any consideration after the invention. This implies the U.S. case. Matters on service invention are specified in employment contracts, and thus firms do not have to provide any consideration as compensation of the invention after success of invention. It is sufficient for firms to pay the wage or prize specified in employment contracts.

In the employees' ownership case, there are two cases to consider: one is the case that employees keep their own rights, and the other is that the rights of new technologies are transferred to the firms from the employees.

Actually, these two cases are equivalent. Employees have no option to use new technologies by themselves although they can make license contracts with other firms to get license fees. Hence, employees get only license fees when they own the patent rights of new technologies. This is the scenario when employees keep the right of invention. On the other hand, when the right of invention is transferred to firms, firms are required to provide the reasonable consideration as compensation of the invention. If the reasonable consideration as compensation of service invention is equivalent to revenue from license contracts with other firms, the employees' reward are equivalent in both cases. Firms can get only profit from free non-exclusive license of the specific characteristic of new technologies, but cannot get any profit from the non-specific characteristic of new technologies, which is the origin of the employees' income. In summary, firms get profit from both characteristics of new technologies and employees get only wage in the firm's ownership case. In the employee's ownership case, firms get net profit only from the specific characteristic and employees get wage and license fee or the reasonable consideration of invention.

We use the multitask contract model by Holmstrom and Milgrom (1991) to consider the problem. Our result is simple. When employed researchers own the rights of the new technologies, excess incentives are given to employees. R&D activities never escape from failures and risks. As the moral hazard theory is well known, the trade-off

relationship between incentives and risks exists. In the case of risk neutral firms and risk averse employees, it is efficient for the firms to bear any risk cost. When the firms own the rights of new technologies and do not have to provide the reasonable consideration after the invention, firms can design the (second best) optimal incentive schemes to employees. However, when employees have the rights of new technologies, this situation is the Japanese and German case, workers face excess incentive schemes. This is inefficient and cannot conduct the second best welfare. Hence, we conclude that the matters on service invention in Japanese patent law should be amended from the viewpoint of the trade-off relationship between employees' incentives and risk aversion: firms should have the rights of new technologies in the case of service invention.

There is another distortion in the case of the employee's ownership. The firm cannot observe not only how much amount of efforts the employed researcher makes but also which characteristics he pays much attention into. He is willing to devote his resources to what he likes. Actually, in the case of Blue LED, professor Nakamura mentioned that a plan on the development of Blue LED which he proposed has not been accepted by his managers.[3] We consider how the difference between the firms' ownership and the employees' one distorts the research behaviors. In the case of the employees' ownership, the firms can use the new technologies without paying any license fee. The employees cannot receive the license fee from the incumbent firms, however, they can get reward from the non-specific characteristic of new technologies by making license contracts with outside firms. Hence, the employees' ownership makes the employees pay more attention into developing the non-specific characteristic of new technologies. This kind of distortion disappears in the case of the firms' ownership. This is another reason that the firms' ownership is better than the employees' one in the case of service invention.

Moreover, we consider the case that firms and employees cannot make contracts contingent on the value of invention. In the real world, the firms' evaluation on new technologies is often different from the employees' evaluation on them. If a new technology produces effective value and profit, it can take long time to ascertain the actual value and profit produced by the new technology. Employees face the uncertain evaluation on new technologies. Firms are willing to under-evaluate them to decrease the compensation of service invention, however, employees have incentives of over-evaluation to get high payment. In this situation, it is difficult to make contracts based on the value of invention, and thus employees can be discouraged from making

[3] Weekly Toyo-Keizai (in Japanese), p101 September 22, 2001

efforts for invention unless they own the patent right of new technologies. This is a kind of situation of contractual incompleteness. In this situation, it is difficult for firms to encourage employed researchers to develop new technologies, and thus rights of new technologies should belong to employees. Risk problem and behavior distortion are left, however, the ownership of rights of new technologies maintains the employees' incentives even if their incentives are excessively given. In the situation of contractual incompleteness, employee's ownership can be better than the firm's ownership.

There are many studies on patent right from the viewpoint of designing optimal patent right. Researchers pay much attention to patent design and consider the optimal combination of protected range and period. For example, we can raise Klemperer (1990), Gilbert and Shapiro (1990), Hopenhayn and Mitchell (2001), and so on. However, few literatures on service invention exist. We apply the moral hazard theory to service invention, and then the results from our model are not sufficiently surprised from the theoretical viewpoints, however, it gives effective way on the recent hot issue on service invention.

2. The Model

A firm employs a worker for R&D activities. New technologies have two kinds of characteristics: one is the specific characteristic that the firm can use for its own activities like producing outputs and services, and the other is the non-specific characteristic that the firm cannot or will not use by themselves. The former characteristic is the firm or industry specific and yields some advantage to the firm in the competition. The latter one does not lead to advantage to the firm directly because the firm does not have appropriate options and know how to use it. However, the firm can get license fees by making license contracts with other firms.

There are two types of ownership of new technologies. We focus on the difference of between the firm's ownership and the employee's one of new technologies.

1. The firms' ownership

An employed researcher can devote his efforts or attention into two parts: the (firm or industry) specific characteristic and the non-specific one. His total efforts are denoted by $\mu = \mu_s + \mu_n$, where subscript *s* means the specific characteristic and *n* does the non-specific one. Effort cost is given by $c(\mu)$, and effort cost function is strictly

convex: c′>0, c">0, c(0)=0, and $\lim_{\mu\to 0} c(\mu) = 0$. New technologies yield revenue which depends on the worker's effort level and luck: $R_s = k_s\mu_s + \varepsilon_s$ and $R_n = k_n\mu_n + \varepsilon_n$. k_i $(i = s, n)$ implies the effectiveness of the characteristic of the new technology and ε_i $(i = s, n)$ means random shock following the normal distribution: $\varepsilon_i \sim N[0, \sigma^2]$ $(i = s, n)$. ε_s and ε_n are identically and independently distributed. The firm cannot observe the worker's effort level but revenue. Even if the employed researcher devotes no effort to the development of the specific (non-specific) characteristic, the development of specific (non-specific) one can be succeeded due to his luck. This setting means that R&D activities cannot escape from risk and uncertainty.

Worker's utility function is given by the exponential form: $U = -\exp\left(-\{w - c(\mu)\}\right)$, where *w* means wage. In this paper, it is assumed that absolute risk aversion is 1 for simplicity. Following Holmstrom and Milgrom (1987), we consider the case of linear payment schemes. The firm offers a linear wage scheme to the worker: $w = \alpha_s R_s + \alpha_n R_n + \beta$. Thus, his expected utility is given by

$$\begin{aligned} EU &\equiv \iint -\exp\left(-\{w - c(\mu)\}\right)\phi(\varepsilon_s)\phi(\varepsilon_n)d\varepsilon_s d\varepsilon_n \\ &= -\exp\left[-\left\{\alpha_s k_s\mu_s + \alpha_n k_n\mu_n + \beta - c(\mu) - \frac{\sigma^2(\alpha_s^2 + \alpha_n^2)}{2}\right\}\right], \end{aligned}$$

where $\phi(\varepsilon_i)$ is the density function of the normal distribution on ε_i $(i = s, n)$. Reservation utility is $\bar{U} \equiv \exp(0) = -1$. Individual rationality is given by $EU \geq \bar{U}$. Since the firm is willing to offer the minimum wage payment, individual rationality is binding on the equilibrium path:

$$\alpha_s k_s\mu_s + \alpha_n k_n\mu_n + \beta - c(\mu) - \frac{\sigma^2(\alpha_s^2 + \alpha_n^2)}{2} = 0.$$

Thus, the firm's expected profit is given by

$$\Pi = R_s + R_n - w = k_s\mu_s + k_n\mu_n - c(\mu) - \frac{\sigma^2(\alpha_s^2 + \alpha_n^2)}{2}.$$

Given the linear wage scheme, the employee determines his effort allocation as follows:

$$\text{if } \alpha_s k_s \geq \alpha_n k_n, \ \mu_s = (c')^{-1}(\alpha_s k_s) \ \textit{and} \ \mu_n = 0 \qquad ...(1)$$

and

$$\text{if } \alpha_s k_s < \alpha_n k_n, \ \mu_s = 0 \ \textit{and} \ \mu_n = (c')^{-1}(\alpha_n k_n) \qquad ...(2)$$

From symmetry, the firm is willing to encourage the employee to make efforts at more beneficial section. Hence, the firm offers as follows:

$$\alpha_n = 0 \ \textit{if} \ k_s \geq k_n$$

and

$$\alpha_s = 0 \ \textit{if} \ k_s < k_n .$$

In the case of $k_s \geq k_n$, the firm offers $\alpha_n = 0$, and thus $\mu_n = 0$. The firm minimizes risk premium on the non-specific characteristic of the new technology by offering $\alpha_n = 0$. In this case, the employee can face no risk on the development of the non-specific characteristic. Although the employee devotes no effort to the development of the non-specific characteristic: $\mu_n = 0$, the revenue that the firm gets from the non-specific characteristic can be positive or negative due to the existence of luck (random shock) ε_n and the revenue belongs to the firm. This implies that invention often depends essentially on luck in the real world. When the firm makes the worker concentrate into the development of the specific characteristic by offering $\alpha_n = 0$, the firm's expected profit is given by

$$\Pi_s = k_s \mu_s - c(\mu_s) - \frac{\sigma^2 \alpha_s^2}{2} \quad \textit{under} \quad k_s \geq k_n .$$

The firm offers the linear wage scheme to maximize the expected profit. The first order condition is

$$\frac{\partial \Pi}{\partial \mu_s} = k_s - c'(\mu_s) - \sigma^2 \alpha_s \frac{\partial \alpha_s}{\partial \mu_s} = 0 . \qquad ...(3)$$

Differentiating (1),

$$\frac{d\alpha_s}{d\mu_s} = \frac{c''}{k_s} > 0 . \qquad ...(4)$$

Substituting (4) into (3), it is obtained that

$$\alpha_s = \alpha_s^* \equiv \left(1 + \frac{\sigma^2 c''}{k_s^2}\right)^{-1} < 1 . \qquad ...(5)$$

Hence, the expected profit of the firm is given by

$$\Pi_s = k_s \mu_s^* - c(\mu_s^*) - \frac{\sigma^2 (\alpha_s^*)^2}{2} \quad under \quad k_s \geq k_n , \qquad ...(6)$$

where $\mu_s^* \equiv (c')^{-1}(\alpha_s^* k_s)$. The case of $k_s < k_n$ is similar to the case of $k_s \geq k_n$.

2. The employees' ownership

If an employed researcher has the rights of new technologies, he can get revenue as license fees by making license contracts. In Japan and Germany, there is a principle of service invention. In the case of service invention, the employee who succeeded in the development of new technologies must provide the employer with non-exclusive license. The firm can use the new technology for its own activities like producing outputs and services for free, but cannot make license contracts with other firms. The employee can make license contracts with other firms. Under this situation, the firm can use only the specific characteristic of the new technology.

We consider the case of the employee's ownership in this section. The firm gets only the revenue from the specific characteristic, but no license fee from the non-specific one. The employee gets the license fee since he owns the patent of the non-specific characteristic of the new technology.

As we indicated in Introduction, the employee's ownership case involves the case that the firm must provide reasonable consideration as compensation of service invention when the all rights of service invention is transferred to the firm from the

employee. For example, in Japan and Germany, there is the forcible provision on reasonable consideration for service invention. Even if the firm and the worker make the contract to agree that all rights of new technologies are transferred to the firm, the firm must provide the reasonable consideration to the employee after the invention. The employee is unwilling to agree transfer of all rights of the new technology if the reasonable consideration is less than license fees on making license contracts. When the reasonable consideration is equivalent to income from the license fee, the forcible provision on service invention is regarded as the employee's ownership.

The firm cannot assign an incentive payment scheme to the revenue from the non-specific characteristic of the new technology because the employee has all rights of the technology. The firm can assign an incentive scheme only on the specific characteristic of the new technology: $w^W = \alpha_s^W R_s + \beta^W$. Thus, the employee's utility in this case is given by $U^W = -\exp\left[-\{\alpha_s^W R_s + R_n + \beta^W - c(\mu^W)\}\right]$. Similarly, the expected utility is as follows:

$$EU^W = -\exp\left[-\left\{\alpha_s^W k_s \mu_s^W + k_n \mu_n^W + \beta^W - c(\mu^W) - \frac{\sigma^2((\alpha_s^W)^2+1)}{2}\right\}\right],$$

where upperscript W means the case of the employee's ownership. Since the firm must satisfy individual rationality: $EU^W \geq \bar{U}$, it holds that

$$\alpha_s^W k_s \mu_s^W + k_n \mu_n^W + \beta^W - c(\mu^W) - \frac{\sigma^2((\alpha_s^W)^2+1)}{2} = 0. \qquad ...(7)$$

The firm's expected profit in the case of the employee's ownership $\Pi^W = R_S - w^W$ is given by

$$\Pi^W = k_s \mu_s^W + k_n \mu_n^W - c(\mu^W) - \frac{\sigma^2((\alpha_s^W)^2+1)}{2}. \qquad ...(8)$$

Now, we consider the employee's behavior. The employee is willing to devote his all efforts into more beneficial development. If $\alpha_s^W k_s \geq k_n$ holds on the equilibrium path,

marginal income the worker gets is higher in the development of the specific characteristic of technologies than in the development of the non-specific one, *vice versa*. Thus, in the case of $\alpha_s^W k_s \geq k_n$, it holds that

$$\mu_s^W = (c')^{-1}\left(\alpha_s^W k_s\right) \quad and \quad \mu_n^W = 0. \qquad ...(9)$$

On the other hand, in the case of $\alpha_s^W k_s < k_n$, it holds that

$$\mu_n^W = (c')^{-1}\left(k_n\right) \quad and \quad \mu_s^W = 0. \qquad ...(10)$$

When the firm encourages the employee to devote his all efforts into the development of the non-specific characteristic of technologies, the firm is willing to offer $\alpha_s^W = 0$. In this case, $\alpha_s^W = 0$ is optimal since it minimizes the risk premium. Hence, the firm's expected profit is given by

$$\Pi_n^W = -\beta^W = k_n \mu_n^W - c(\mu_n^W) - \frac{\sigma^2}{2}. \qquad ...(11)$$

In this model, the relative difference between k_s and k_n is crucial, and thereby we normalize k_n to one: $k_n \equiv 1$. Then, we analyze the effect of increase of k_s. Clearly, Π_n^W is independent of k_s from (11).

Next, we consider the case wherein the firm makes the employee concentrate on the specific characteristic of technologies. The firm must offer more attractive wage scheme in the development of the specific characteristic of technologies than in the development of the non-specific one:

$$\alpha_s^W k_s \geq k_n \equiv 1. \qquad ...(12)$$

It is a constraint the firm faces when the firm makes the employee pay all attention to the development of the specific characteristic of technologies.

First, we consider the case such that (12) is not binding on the equilibrium. In this situation, the firm can offer payment schemes as if the constraint (12) does not exist, and thus the employee makes no effort in the development of the non-specific characteristic of technologies: $\mu_n^W = 0$. Thus, the firm's expected profit in this case is

$$\Pi_s^W\Big|_{no(12)} \equiv k_s\mu_s^W - c(\mu_s^W) - \frac{\sigma^2((\alpha_s^W)^2+1)}{2}, \qquad ...(13)$$

where the expected profit without the constraint (12) is denoted as $\Pi_s^W\Big|_{no(12)}$. Note that the employee faces the risk on the development of the non-specific characteristic of technologies even if $\mu_n^W = 0$. This risk is caused by the employee's patent ownership of new technologies. This is different from the case of the firm's ownership. As the similar manner to the case of the firm's ownership,

$$\alpha_s^W = \alpha_s^{W*} \equiv \left(1+\frac{\sigma^2 c''}{k_s^2}\right)^{-1} < 1. \qquad ...(14)$$

From (5) and (14), it holds given k_s that

$$\alpha_s^* = \alpha_s^{W*}. \qquad ...(15)$$

The firm's profit is given by $\Pi_s^W\Big|_{no(12)} \equiv k_s\mu_s^{W*} - c(\mu_s^{W*}) - \frac{\sigma^2((\alpha_s^{W*})^2+1)}{2}$, where $\mu_s^{W*} \equiv (c')^{-1}(\alpha_s^{W*}k_s)$. When the constraint (12) is not binding, the following lemma is obtained.

Lemma 1

α_s^{W*} increases with respect to k_s.

Proof is easy and in Appendix. The constraint (12) means that α_s^W decreases with respect to k_s. Using lemma 1, a critical point $\tilde{k}_s$ exists such as the constraint (12) is not binding under $k_s > \tilde{k}_s$ and (12) is binding under $k_s \leq \tilde{k}_s$. See figure 1.

Since the constraint (12) is binding under $k_s \leq \tilde{k}_s$, the firm must offer $\alpha_s^W = \frac{1}{k_s}$ in order to make the employee concentrate on the specific characteristic of technologies. In this case, from (9) and (10), it holds that

$$\mu_s^W = (c')^{-1}(1). \qquad ...(16)$$

The firm's expected profit in this case is given by

$$\Pi_s^W\Big|_{\alpha_s^W k_s=1} \equiv k_s(c')^{-1}(1) - c\left((c')^{-1}(1)\right) - \frac{\sigma^2}{2k_s^2} - \frac{\sigma^2}{2}. \qquad ...(17)$$

When the constraint (12) is binding, the firm's expected profit is denoted as $\Pi_s^W\Big|_{\alpha_s^W k_s=1}$. Thus, figure 2 is obtained.[4][5] The profit without the constraint (12) which is denoted as

---

[4] Using the envelope theorem and (1), it holds that $\frac{d\,\Pi_s^W\Big|_{no(12)}}{dk_s} = \mu_s^{W*} > 0$ and $\frac{d^2\,\Pi_s^W\Big|_{no(12)}}{d(k_s)^2} = \frac{d\mu_s^{W*}}{dk_s} > 0$. Also, it is obtained that $\frac{d\,\Pi_s^W\Big|_{\alpha_s k_s=1}}{dk_s} = (c')^{-1}(1) + \frac{\sigma^2}{k_s^3} > 0$ from (16) and $\frac{d^2\,\Pi_s^W\Big|_{\alpha_s k_s=1}}{d(k_s)^2} = -\frac{3\sigma^2}{k_s^4} < 0$. Thus, $\Pi_s^W\Big|_{no(12)}$ is convex and $\Pi_s^W\Big|_{\alpha_s k_s=1}$ is concave with respect to k_s. Next, we consider the curve of the firm's profit when the firm makes the employee pay his all attentions to the non-specific characteristic of technologies. In this case, Π_n^W is horizontal to k_s because it is independent of k_s from (11). Hence, figure 2 is obtained.

[5] In figure 2, we draw the case wherein $\tilde{k}_s$ is less than $\hat{k}_s$. The case of $\hat{k}_s \leq \tilde{k}_s$ can happen, however, our results are not affected as we show later.

$\Pi_s^W\big|_{no(12)}$ is more than the profit with (12) given by $\Pi_s^W\big|_{\alpha_s^W k_s=1}$, and these are equal at the point of $k_s=\tilde{k}_s$. Thus, when the firm makes the employee concentrate on the development of the specific characteristic of technologies, the expected profit is given as follows:

$$\Pi_s^W=\begin{cases}\Pi_s^W\big|_{no(12)} & if \quad k_s\geq\tilde{k}_s\\ \Pi_s^W\big|_{\alpha_s^W k_s=1} & if \quad k_s<\tilde{k}_s\end{cases}. \qquad ...(18)$$

Hence, the expected profit Π_s^W increases with respect to k_s.

Next, we consider the difference between Π_s^W and Π_n^W.

Lemma 2

A critical point $\hat{k}_s$ exists: if $k_s\geq\hat{k}_s$, the firm makes the employee pay his all attention into the development of the specific characteristic of technologies rather than that of the non-specific characteristic, *vice versa*. The firm's expected profit is $\Pi^W=\begin{cases}\Pi_s^W & if \quad k_s\geq\hat{k}_s\\ \Pi_n^W & if \quad k_s<\hat{k}_s\end{cases}$. The critical point $\hat{k}_s$ is strictly more than 1: $\hat{k}_s>1\equiv k_n$.

Proof is in Appendix. Lemma 2 indicates that the firm encourages the employee to devote his attention to the development of the specific characteristic of technologies when the specific characteristic of technologies is more beneficial than the non-specific one. Under $k_s\geq\hat{k}_s$, the firm encourages the employee to make his efforts into the development of the specific characteristic of technologies, otherwise, the firm makes the employee pay any attention into the development of the non-specific characteristic of technologies. The switching point $\hat{k}_s$ between the specific and the non-specific characteristics is more than 1 in the case of the employee's ownership. In contrast, in the case of the firm's ownership, the switching point is equivalent to 1 and efficient. In the

case of the employee's ownership, the development of the non-specific characteristic of technologies is more attractive for the employee because he faces the outcomes of the development of the non-specific characteristic directly. Hence, the firm has to offer stronger incentive schemes to make the worker devote his efforts into the development of the specific characteristic of technologies. Excess incentive schemes lead to decline of the profit from the development of the specific characteristic of technology, and thereby the attractiveness of the specific characteristic must be large when the firm makes the employee concentrate his attention into the development of the specific characteristic of technologies. Unless attractiveness of the specific characteristics is sufficiently large, the firm is unwilling to encourage the employee to do research activities in the development of the specific characteristic. Therefore, the switching point between the specific and the non-specific characteristics is more than 1 in the case of the employee's ownership.

Proposition 1

[1] If $k_s \geq \hat{k}_s$ and $k_s \geq \tilde{k}_s$, it holds that $\alpha_s^W = \alpha_s^{W*} (= \alpha_s^*)$, $\mu_s^W = \mu_s^{W*} \left(= \mu_s^* \equiv (c')^{-1} \left(\alpha_s^* k_s \right) \right)$, and $\mu_n^W = 0$. [2] If $\tilde{k}_s \geq k_s \geq \hat{k}_s$, it holds that $\alpha_s^W = \frac{1}{k_s}$, $\mu_s^W = (c')^{-1}(1)$, and $\mu_n^W = 0$. [3] If $k_s < \hat{k}_s$, it holds that $\alpha_s^W = 0$, $\mu_s^W = 0$, and $\mu_n^W = (c')^{-1}(1)$.

Proof is easy. Case [1]: $k_s \geq \hat{k}_s$ and $k_s \geq \tilde{k}_s$. Under $k_s \geq \hat{k}_s$, the firm makes the employee concentrate into the development of the specific characteristic of technologies. Thus, $\mu_s^W = \mu_s^* \equiv (c')^{-1} \left(\alpha_s^* k_s \right)$ and $\mu_n^W = 0$ hold since (12) is not binding from $k_s \geq \tilde{k}_s$. The firm offers $\alpha_s^W = \alpha_s^{W*} (= \alpha_s^*)$ from (15).

Case [2]: $\tilde{k}_s \geq k_s \geq \hat{k}_s$. In the case of $\tilde{k}_s \geq k_s \geq \hat{k}_s$, (12) is binding although the firm has incentives of making the employee pay any attention into the development of the specific characteristic of technologies. Hence, it is obtained that $\alpha_s^W = \frac{1}{k_s}$,

$\mu_s^W = (c')^{-1}(1)$, and $\mu_n^W = 0$.

Case [3]: $k_s < \hat{k}_s$. The firm is willing to make the employee concentrate into the development of the non-specific characteristic of technologies. It holds that $\alpha_s^W = 0$, $\mu_s^W = 0$, and $\mu_n^W = (c')^{-1}(1)$.

Figure 3 shows which characteristics of technologies the employee pays his attention into. The non-specific characteristic of technologies is more likely to be developed in the employee's ownership case than in the firm's ownership one.

Proposition 2

The firm's profit in the case of the firm's ownership is more than that in the case of the employee's ownership: $\Pi > \Pi^W$.

Proof is in Appendix. Reward from the non-specific characteristic of new technologies belongs to the employee in the employee's ownership. We can regard this case as the situation in which the firm faces a constraint on the incentive scheme of the non-specific characteristic of new technology: $a_n^W = 1$. In contrast, there is no constraint like this in the case of the firm's ownership. The case with the existence of the constraint is dominated by the case without the constraint.

There are two causes to obtain proposition 2. One is a risk problem. The risk problem is alleviated in the firm's ownership case because the firm can design the second best incentive scheme. In the employee's ownership case, the employee faces the excess incentive scheme, as a result, he is suffered from the risk problem. The other is the distortion on which characteristic the employee devotes his efforts and attention into. Distortion on the employee's attention appears in the employee's ownership case although it disappears in the firm's ownership. These two negative effects decrease the firm's profit in the employee's ownership case. Since the worker's expected utility is always equivalent to the level of the outside option $\bar{U}$, $\Pi > \Pi^W$ indicates that the firm's ownership improves social welfare rather than the employee's ownership.

3. Contractual Incompleteness

In chapter 2, we have considered the situation that firms and employees can make contracts contingent on the value of new technologies. However, this kind of complete contract may be difficult to be enforced. The value of new technologies can be uncertain even after success of invention because it takes long time to fix the value. As the result, firms are willing to under-evaluate the value to decrease payment of invention, however, the employees have incentives of over-evaluation.

When it is difficult to make contracts based on the value of invention between firms and employees, firms cannot encourage employed researchers in the case of the firms' ownership. Hence, employees make no effort to invention: $\mu_s = \mu_n = 0$. The expected profit is zero in this case.

Under contractual incompleteness, the patents of service invention may belong to employees from the viewpoint of their incentives. When employees own the patent rights of invention, as we have shown in chapter 2, employees have incentives of invention. Unfortunately, risk and behavior distortion problem exist, and thus we cannot avoid these problems at all because we cannot make the second best contracts between firms and employees in this situation. However, we get positive expected profit and social welfare.

4. Conclusions and Discussions

We have considered the linear wage scheme case and shown that the firm's ownership of rights on service invention is more desirable than the employed researcher's ownership.[6] In the case of the researcher's ownership, there are two types of distortions. One is inefficient risk sharing between the firm and the employee. Following the typical moral hazard model with a risk neutral principal and a risk averse agent, the employee's ownership case yields excess incentives to the employee. Moreover, since the development of the non-specific characteristic of technologies is more attractive for the employee, the employee is willing to pay his attention into the development of the non-specific characteristic of technologies. This is the other

[6] Following Holmstrom and Milgrom (1991), we used linear wage schemes under the random shock followed by normal distribution to consider the distortion of the employee's behavior. In the real world, discovery or invention might not be followed by normal distribution, however, our setting with linear payment schemes and normal distribution is simple and useful to analyze the behavior distortion of employed researchers. Even if the distribution is not normal, risk problem we consider is clearly left, and thus the firm's ownership is better than the employee's one.

distortion caused by the employee's ownership of rights on service invention.

Recently, we often observe opinions that employed researchers should be well treated by firms in Japan. However, in the case of service invention, it is inefficient to give the rights of new technologies in service invention to employed researchers. Our model in this paper is a typical multitask moral hazard model and gives few new results from the viewpoint of theoretical work, though, the model gives an effective viewpoint to service invention problems on who should have rights of new technologies in service invention. From our results, it can be myopic that employees should have any rights of service invention or receive reasonable consideration after invention, which is specified in Japanese patent law.

As we considered in chapter 3, contractual incompleteness modifies the result. When the value of invention is not fixed easily, firms cannot encourage employees to do R&D activities well by making incentive scheme contracts with employees. In this situation, the employees' ownership of rights of new technologies can yield incentives to employees although the incentive schemes the employees face are excessive.

We raise some cases wherein specification on the value of invention is difficult. First, the value of the invention is small, but the invention is necessary to develop next-generation technologies. The invention might be the first innovation essential to the second one with big value. Although the value of the first innovation may be small, it can yield huge profit in the future. As Scotchmer and Green (1990), Sctchmer (1996), Aoki and Prusa (1996), Denicolo (2000), and Choi (2002) consider, protection of early innovator is a crucial problem in the real world. Originally, studies on patent right focus on infringement of patent right and information disclosure on early innovation. The same problem exists in the case of service invention.

Moreover, the value of new technologies does not appear clearly when firms use the new technologies to make cross-license contracts with other firms. Cross-license contracts allow a firm to use the other firm's technologies without paying any license fee each other. In this situation, the value of invention is not determined clearly although cross-license contracts are very often made to avoid the conflicts on the infringement of patent right.

In these situations, it is difficult to measure the value of invention. It is an open question what situation measurement of the value is not only difficult but also crucial in. Recently, many Japanese firms introduce various types of incentive schemes on service invention to improve employees' incentives. From the empirical viewpoint, it is a future work to survey how these incentive schemes actually work for employees' incentives.

Finally, we point out the cost on making license contracts and managing patent

rights. Employed researchers can make license contracts with other outside firms at no cost in this paper. You will probably feel that this assumption is not realistic. Applying patents, making license contracts, and managing patents yield huge cost. There is scale merit of managing patents, and thereby the employee's ownership is dominated by the firm's one. Although we ignore the effect in this paper, we have shown that the firm's ownership is more desirable. Considering this effect strengthens our results.

Appendix

Proof of lemma 1

The first order condition of (13) is given by $\frac{\partial \Pi_s^W\big|_{no(12)}}{\partial \mu_s^W} = 0$. Differentiate this condition with respect to μ_s^W and k_s:

$$\frac{\partial^2 \Pi_s^W\big|_{no(12)}}{\partial (\mu_s^W)^2} d\mu_s^W + \frac{\partial^2 \Pi_s^W\big|_{no(12)}}{\partial k_s \partial \mu_s^W} dk_s = 0 .$$

It holds that $\frac{\partial^2 \Pi_s^W\big|_{no(12)}}{\partial (\mu_s^W)^2} \le 0$ from the second order condition and $\frac{\partial^2 \Pi_s^W\big|_{no(12)}}{\partial k_s \partial \mu_s^W} = 1$. Thus,

$$\frac{dk_s}{d\mu_s^W} = -\left(\frac{\partial^2 \Pi_s^W\big|_{no(12)}}{\partial (\mu_s^W)^2} \right) \Bigg/ \left(\frac{\partial^2 \Pi_s^W\big|_{no(12)}}{\partial k_s \partial \mu_s^W} \right) \ge 0 .$$

This implies that μ_s^W increases with respect to k_s. Using this result and (4), α_s^{W*} increases with respect to k_s.■

Proof of lemma 2

Π_s^W increases with respect to k_s and Π_n^W is independent of k_s. Since it holds from (17) that $\Pi_s^W\big|_{\alpha_s^W k_s=1} \to -\infty$ as $k_s \to 0$ and Π_s^W is continuously increasing with respect to k_s, there is a level of $\hat{k}_s$ such that $\Pi_s^W(\hat{k}_s) = \Pi_n^W$. Under $k_s = 1 (\equiv k_n)$, it holds from (16) that $\Pi_n^W - \Pi_s^W\big|_{no(12)} = \dfrac{\sigma^2}{2} > 0$. As figure 2 implies, $\hat{k}_s > 1$ is obtained because $\Pi_s^W\big|_{no(12)}$, $\Pi_s^W\big|_{\alpha_s^W k_s=1}$, and Π_s^W increase with respect to k_s.■

Proof of proposition 2

First, we will show $\Pi_s > \Pi_s^W$. If the constraint (12) is not binding, from proposition 1, $\alpha_s^* = \alpha_s^{W*}$ and $\mu_s^* = \mu_s^{W*}$ holds. Using (6) and (13), it is obtained that $\Pi_s - \Pi_s^W\big|_{no(12)} = \dfrac{\sigma^2}{2} > 0$. Next, we consider the case such that the constraint (12) is binding. Since the constraint (12) is binding, the expected profit is worse in this case than the case that (12) is not binding. Hence, it holds that $\Pi_s^W\big|_{no(12)} \geq \Pi_s^W\big|_{\alpha_s^W k_s=1}$ for any k_s. This inequality strictly holds under $k_s \neq \tilde{k}_s$. Therefore, it holds from (18) that $\Pi_s > \Pi_s^W\big|_{no(12)} \geq \Pi_s^W$.

Next, we will show $\Pi_n \geq \Pi_n^W$. From symmetry and (6), when the firm makes the employee concentrate into the development of the non-specific characteristic of technologies, the expected profit in the case of the firm's ownership is given by

$$\Pi_n = \mu_n - c(\mu_n) - \frac{\sigma^2(\alpha_n)^2}{2}. \qquad \text{...(A1)}$$

The firm can optimize the incentive scheme α_n. However, in the case of the employee's

ownership, the firm cannot optimize α_n since the employee owns the patent right of the technologies. This situation is similar to the case that the firm face a constraint: $\alpha_n^W = 1$. Since it holds that the optimal solution on (A1) is given by $\alpha_n^* < 1$ from the similarity of (5), the existence of the constraint reduces the expected profit of the firm: $\Pi_n > \Pi_n^W$.

It holds that $\Pi = \max\{\Pi_s, \Pi_n\}$ and $\Pi^W = \max\{\Pi_s^W, \Pi_n^W\}$. From $\Pi_s > \Pi_s^W$ and $\Pi_n > \Pi_n^W$, it is obtained that $\Pi > \Pi^W$.■

Reference

Aoki, Reiko, and Thomas J. Prusa (1996) "Product Development and the Timing of Information Disclosure under U.S. and Japanese Patent Systems", *Journal of the Japanese and International Economies*, 10, 233-249.

Choi, Jay P. (2002) "A Dynamic Analysis of Licensing: The 'Boomerang' Effect and Grant-back Clauses", *International Economic Review*, 43, 803-829.

Denicolo, Vincenzo (2000) "Two-stage Patent Races and Patent Policy", *Rand Journal of Economics*, 31, 488-501.

Foster, Frank H., and Robert L. Shook (1989) "Patents, Copyrights and Trademarks", John Wiley & Sons, Inc.

Gilbert, Richard and Carl Shapiro (1990) "Optimal Patent Length and Breadth", *Rand Journal of Economics*, 21, 106-112.

Holmstrom, Bengt and Paul Milgrom (1987) "Aggregation and Linearity in the Provision of Intertemporal Incentives", *Econometrica*, 55, 303-328.

---------- **and** ---------- **(1991)** "Multitask principal-Agent Analysis: Incentive Contracts, Asset Ownership, and Job Design", *Journal of Law, Economics and Organization*, 7, 24-52.

Hopenhayn, Hugo A. and Matthew F. Mitchell (2001) "Innovation Variety and Patent Breadth", *Rand Journal of Economics*, 32, 152-166.

Klemperer, Paul (1990) "How Broad should the Scope of Patent Protection be?" *Rand Journal of Economics*, 21, 113-130.

Ohba, Masashige (2002) "Reasonable consideration of Service Invention" ("Shyokumu-Hatsumei no Soto no Taika", in Japanese), *Chizai Kanri*, 52, 747-759.

Scotchmer, Suzanne (1996) "Protecting Early Innovators: Should Second-generation Products be Patentable?" *Rand Journal of Economics*, 27, 322-331.

---------- **and Jerry Green (1990)** "Novelty and Disclosure in patent Law", *Rand Journal of Economics*, 21, 131-146.

Takeda, Kazuhiko (2002) "Who owns patent rights? On the ownership and requirement in the service invention" ("Tokkyo wa dare no monoka—syokumu hatumei no kizoku to taika", in Japanese), Diamond-sha, Tokyo.

Table 1

Difference of rules of service invention

	Employees' ownership (Japanese case)	Firms' ownership (U.S. case)
Firms' rights	Free non-exclusive license	All rights of invention
Employees' rights	Exclusive license	Nothing

Table 2

Origins of earnings in service invention

	Employees' reward	Firms' profit
Firms' ownership	Wage	Profit from the specific characteristic and License reward on the non-specific characteristic
Employees' ownership	Wage and License reward on the non-specific characteristic	Profit from the specific characteristic

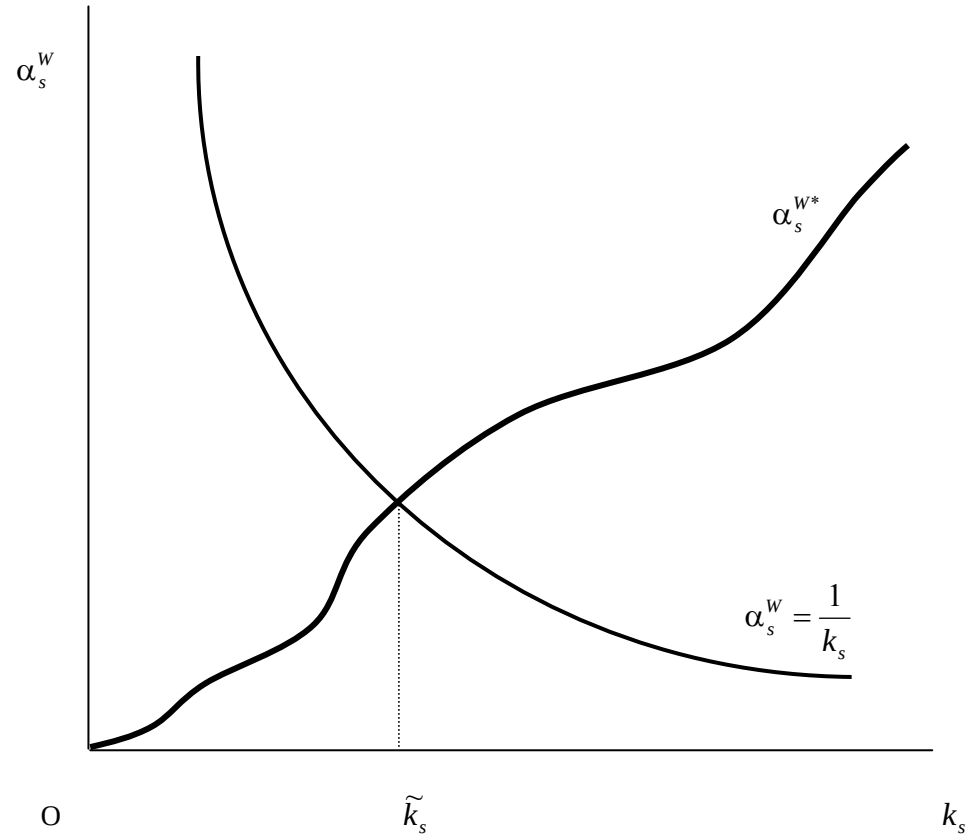

Figure 1

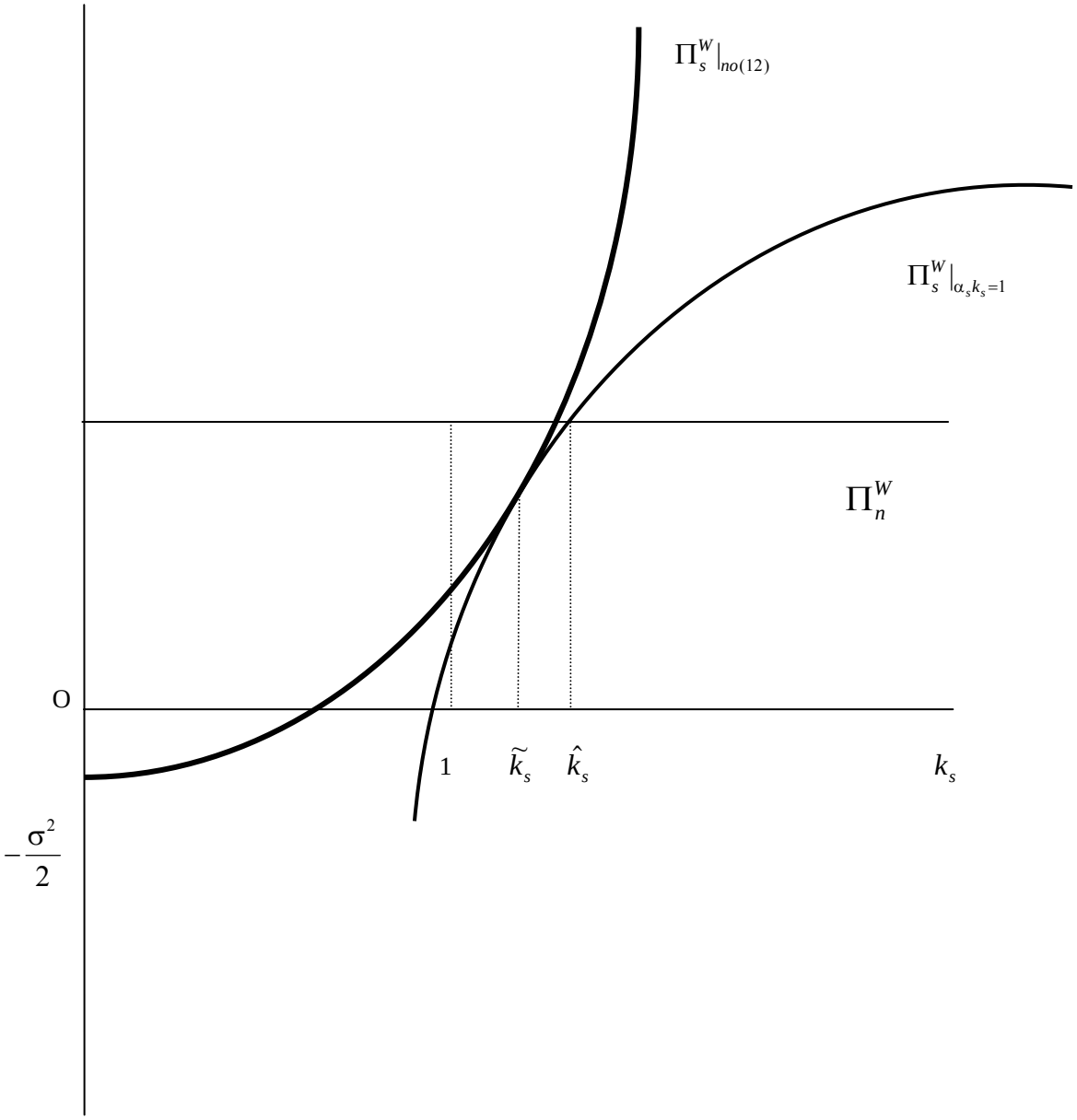
$\Pi_s^W|_{no(12)}$
$\Pi_s^W|_{\alpha_s k_s=1}$
Π_n^W
O
1
$\tilde{k}_s$
$\hat{k}_s$
k_s
$-\frac{\sigma^2}{2}$

Figure 2

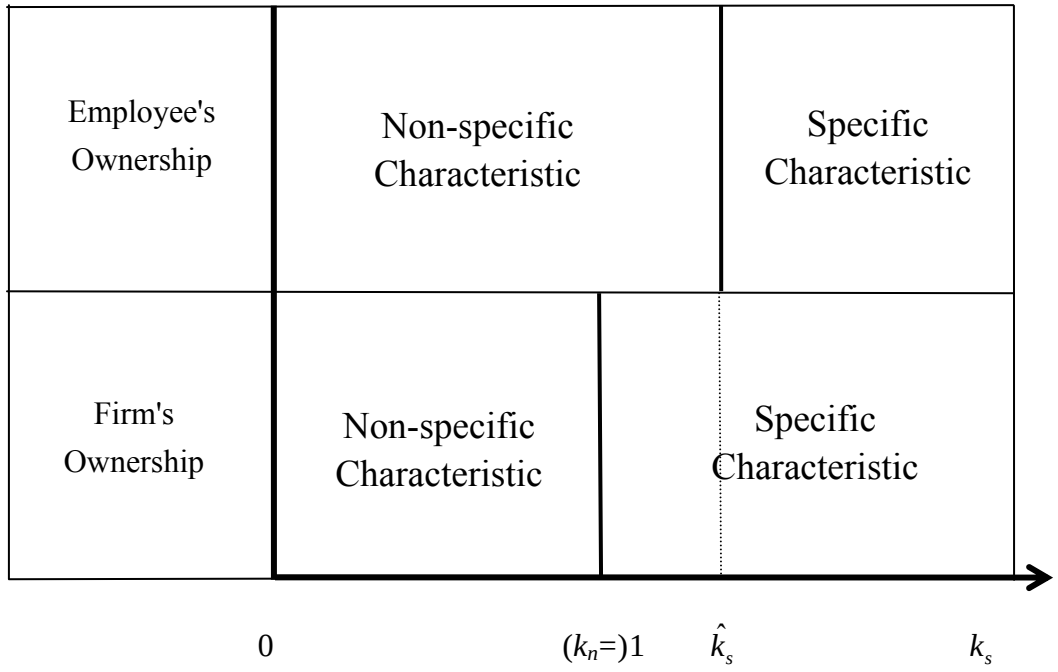
Employee's Ownership
Non-specific Characteristic
Specific Characteristic
Firm's Ownership
Non-specific Characteristic
Specific Characteristic
0
$(k_n=)1$
$\hat{k}_s$
k_s

Figure 3