GRIPS Discussion Paper 17-17

The effects of the assign-back provision on R&D
-An application of the guidelines of the European Union, the United States and Japan-

Kaori Hatanaka

March 2018

GRIPS
NATIONAL GRADUATE INSTITUTE FOR POLICY STUDIES

National Graduate Institute for Policy Studies
7-22-1 Roppongi, Minato-ku,
Tokyo, Japan 106-8677

The effects of the assign-back provision on R&D

-An application of the guidelines of the European Union, the United States and Japan-

Kaori Hatanaka*

National Graduate Institute for Policy Studies

March, 2018

Abstract

We examine the effects on R&D of the assign-back provision in license contracts. When the technical scope of the assign-back is narrow, its expansion decreases investment in the improved technology, but increases that in the original technology. However, when the technical scope is larger than a certain threshold level, its expansion decreases the profit of the licensor of the original technology and reduces the investment in both technologies. Therefore, the licensor would not like to expand the technical scope beyond the threshold. In addition, we apply our result to the guidelines of Japan, the United States, and the European Union.

Key words: license contract, grant-back, game theory

Topic Groups: Microeconomics, Law and Business

JEL Classification: C72, D21, O34

I am grateful to the valuable comments of Hiroyuki Odagiri, Yousuke Okada, Motohiro Nishimura and the other participants in the CPRC workshop for the previous version of this paper.

1. Introduction

A grant-back provision in license contracts means that a licensee is obliged to sell the patent of an improved technology to the licensor at an assigned price (an assign-back provision), or to not charge the licensor for the royalty of the improved technology (a free royalty provision), if the licensee succeeds in the improved technology by using the licensors' patent.

A grant-back provision has benefits and drawbacks. One of the benefits is that it provides a means for the licensee and the licensor to share the risks and to reward the licensor. On the other hand, the grant-back provision is considered to give monopolistic power to the licensor of the original technology, and it reduces the licensees' incentives to engage in R&D. Isabella and Toke (2012) show that a grant-back provision increases the time to invention, using a matched data set of longer by a matched data set of licensees and non-licensees[1].

A grant-back provision is often used in patent pools and today multinational companies often include this provision in license contracts. The governments of the United States, the European Union and Japan have published guidelines for grant-back provisions. However, their treatments of grant-back provisions differs. According to the "Antitrust Guidelines for licensing the intellectual property," (p.26) issued by the U.S. Department of Justice and Fair Trade Commission in 1995,

"An important factor in the Agencies' analysis of a grantback will be whether the licensor has market power in a relevant technology or innovation market. If the Agencies determine that a particular grantback provision is likely to reduce significantly licensees' incentives to invest in improving the licensed technology, the Agencies will consider the extent to which the grantback provision has offsetting procompetitive effects, such as (1) promoting dissemination of licensees' improvements to the licensed technology, (2) increasing the licensors' incentives to disseminate the licensed technology, or (3) otherwise increasing competition and output in a relevant technology or innovation market."

In short, the U.S. guideline focuses on the market power of a technology or in an innovation market and the incentives of dissemination.

On the other hand, in May 2014, the European Union revised its "Technology

[1] They also show that when the licensee is unfamiliar with the licensed technology, a grant-back provision does not decrease the licensees' incentives for R&D.

Transfer Block Exemption Regulation (TTBER)," which exempts licensing agreements concluded between companies that have limited market share[2]. All exclusive grant-back obligations[3] and grant-backs between companies with high market power fall outside the safe harbor of TTBER in order to protect incentives to innovate and the appropriate application of intellectual property rights. The EU regulation focuses on market share.

In Japan, the guideline published by the Japan Fair Trade Commission states that a grant-back is basically "unfair," because it gives monopolistic power to the licensor and reduces the licensees' incentive for R&D. However, from this guideline allows an assign-back provision with an adequate assigned-price for the improved technology.

In this way, the regulation of grant-backs varies among countries and the logic of the regulation is ambiguous. Many believe that it is a serious problem that multinational enterprises can request the broad technical scope of the grant-back from the patent holder of the improved technology. However, from a theoretical perspective it is not clear whether a grant-back increases investment in the original and the improved technology, or whether the licensor of the original technology has an incentive to expand the technical scope of the grant-back by as much as possible.

This study uses game theory to examine the effects of an assign-back provision on the investment in R&D, considering the strategic behavior of firms. Then, we apply the conclusion to the guidelines published by the European Union, the United States and Japan. First, we construct a model of the assign-back and consider its effects on the investment in the original technology and that in the improved technology. In the model, we incorporate the technical scope of the grant-back, that is, the technical range within which to apply the assign-back. For simplicity, this is interpreted as the probability of applying the assign-back. The probability is high when most parts of the original technology are used to obtain the improved technology, or when the licensor of the original technology has high bargaining power and requests the assign-back, even though the improved technology is not derived from the original technology. Thus we consider two cases. In the first case, the technical scope of the grant-back is given as the characteristics of the technology, and in the second, the technical scope is chosen by the

[2] For example, a market share not exceeding 20% for agreements between competitors, and 30% for agreements between non-competitors.

[3] Exclusive grant-back obligations are those where the licensee is obliged to license back to the licensor on an exclusive basis, and not cannot use its own improvements to the licensed technology

licensor of the original technology and committed to in the license contract before choosing the price of the assign-back.

The proposed model is based on that of Hatanaka (2012a, b), who also introduced the technical scope of the grant-back and analyzed whether a grant-back increases investment. In that model, the technical scope and the price of the assign-back are chosen at the same time by the licensor. The author concludes that only when the price of the assign-back is greater than the twice value of the royalties, does a grant-back increase the investment. However, the result is imperfect because the conclusion depends on the endogenous price of the assign-back.

In this study, taking into accounts of recent developments, we examine two cases. In the first case, the technical scope of the grant-back is given as the character of the technology. In the second case, the licensor of the original technology who has significant power, is free to fix the technical scope of the grant-back, which is written and committed in the contract before the success of the improved technology.

We obtain the following results. First, the government should not prohibit grant-backs, because they enhance the dissemination of the original technology. A grant-back increases the licensor's profit and provides the licensor with an incentive to sign a license contract.

Second, when the technical scope is narrow, the licensee will accept zero as the price of the assign-back. An expansion of the technical scope decreases the investment in the improved technology, but increases that in the original technology, because it decreases the licensee's expected profit and the licensor can use the improved technology for free with a higher probability. However, when the technical scope of the grant-back is over a certain threshold level, the licensor must offer a positive price for the assign-back in order to have the licensee join the license contract. In this case, an expansion of the technical scope beyond this threshold decreases the investment of both firms in both technologies. In addition, we find that an increase in the price of the assign-back mitigates the negative effect on the investment in the improved technology.

Third, we examine the case in which the technical scope of the grant-back is chosen by the licensor and committed to in the license contract, before the price of the assign-back is chosen. The licensor of the original technology has no incentive to expand the technical scope of the grant-back by as much as possible, because an expansion of the technical scope beyond the threshold level decreases the investment in the improved technology of both firms and leads to a reduction in the licensor's profit.

Fourth, we apply our results to the guidelines published by the European Union, the United States and Japan. We consider the validity of each of the guidelines. The guidelines of the European Union focus on the share of the product market, whereas those of the United States focus on the power in the technology market. The guidelines of Japan basically prohibit grant-backs, but allow assign-backs with a reasonable assigned price. We apply our theoretical results to these guidelines and consider their validity.

Lerner, Strojwas, and Tirole (2007) examined cases in which grant-backs occur. They find that grant-backs should be associated with pools consisting of complements and allowing independent licensing. However, they do not obtain a desirable regulation for grant-backs and do not discriminate between an assign-back and free royalty provision. Choi (2002) examines the validity of grant-back clauses using the incomplete contract model. He finds that grant-back provisions can relax the incentive compatibility condition (ICC) for licensors and can make them transfer the best technology to the licensees. This result is the same as our first conclusion. In addition, he concludes that if a grant-back provision induces the transfer of the core technology, the grant-back clause enhances R&D, otherwise it may or may not have a positive effect on R&D. He shows that if R&D tends to be duplicative, the effect of a grant-back clause is positive, because it can reduce excessive R&D. However, he does not consider the technical scope of the grant-back.

We also show the trade-off between investing in the original and the improved technology when the technical scope of the assign-back is narrow, as in studies on sequential innovation, such as Scotchmer (1991), Green and Scotchmer (1995) and Denicolo (2000). They show that strong protection of the original technology diminishes investment in the improved technology, and that the desirable patent breadth depends on which technology is more valuable. In the same way, we conclude that the problem of the validity of an assign-back depends on the technical scope of the grant-back and on which technology is more valuable, assuming the technical scope of the grant-back is narrower than the threshold level.

The remainder of the paper is organized as follows. In the next section, we introduce the model used to analyze the assign-back and show the first-best investments. In section 3, we derive the equilibrium when the technical scope of the grant-back is given. Section 4 discusses the case when the technical scope of the grant-back is chosen by the licensor, and section 5 compares the free royalty provision and the assign-back. Section 6 applies our results to the guidelines published by the European Union, the United States and Japan. The final section concludes the paper.

2. The model

2.1 The model of the assign-back

There are two kinds of patentable technologies, namely, the original technology and the improved technology, which cannot be achieved without some parts of the original technology. The original technology reduces a unit cost of production from c_0 to c_1, and the improved technology reduces the cost from c_1 to $c_{2,}$ where $c_0 > c_1 > c_2$.

There exist two risk-neutral firms competing in terms of quantity in a product market and in R&D for these two technologies. We assume that only one firm can own the patent of each technology.

The investment in the original technology by firm i is denoted as $R_i \ (i = 1, 2)$. Then, $\gamma_i = \Gamma(R_i, R_j)$ is the probability that firm i obtains the patent of the original technology, depending on the investment of both firms, R_i and R_j. The probability of success of firm i is increasing by its own investment, but decreasing by the rival's investment, that is, $\Gamma_{i,Ri} > 0, \Gamma_{i,Rj} < 0$. In addition, we assume $\Gamma_{i,Ri,Ri} < \Gamma_{i,Ri,Rj} < 0 \quad (i = 1,2 \ i \neq j)$. Because both of the firms may fail to achieve the technology, we can get $\gamma_i + \gamma_j < 1$.

The investment in the improved technology by firm i is denoted as $D_i \ (i = 1,2)$. Then $\theta_i = \Theta(D_i, D_j)$ is the probability that firm i obtains the patent of the improved technology, depending on the investment of both firms, D_i and D_j. The probability of the success of the improved technology, $\Theta(D_i, D_j)$ has the same characteristics as the probability of success of the original technology, that is, $\theta_i + \theta_j < 1$, $\Theta_{i,Di} > 0, \Theta_{i,Dj} < 0$ and $\Theta_{i,Di,Di} < \Theta_{i,Di,Dj} < 0 \quad (i = 1 or\ 2,\ i \neq j)$.

We express Firm i's profit from the products without the royalty in a Cournot equilibrium when Firm i's cost is c_m and Firm j's cost is c_n (where $m, n = 0,1,2,$) as $\pi(c_m, c_n)$. For simplicity, when both firms' costs are equal at c_n, each profit is denoted as $\pi(c_n)$.

The royalties of the original technology and the improved technology are assumed to be given in the market as $f_R (0 < f_R < 1/2)$ and $f_D (0 < f_D < 1/2)$ of the profit of the licensee[4]. Thus if Firm 1 succeeds in the original technology and signs the license contract with Firm 2, the profits of Firm 1 and Firm 2 are $((1+f_R)\pi(c_1),(1-f_R)\pi(c_1))$.

Now we explain the actions of each firm. At the first stage, each firm chooses its investment in the original technology. The firm that succeeds in the original technology is called as Firm 1 and the other firm is denoted as Firm 2.

At the second stage, Firm 1 chooses whether to create a license contract for the original technology with Firm 2. If Firm 1 chooses not to create a license contract, it will engage in R&D of the improved technology by itself and obtain

$$\overline{\Pi_1} = Max_{D1} \quad \Theta(D_1,0)\pi(c_2,c_0) + (1-\Theta(D_1,0))\pi(c_1,c_0) - D_1 .$$

On the other hand, if Firm 1 chooses to create a license contract, Firm 1 can insert the grant-back condition. We consider an assign-back, which gives the licensor (Firm 1) the right to purchase the technology from the licensee (Firm 2) at the assigned price, if the licensee succeeds in obtaining the improved technology. Usually the grant-back includes a technical scope. If the licensee (Firm2) succeeds in the improved technology by utilizing the technology in the technical scope, the licensor (Firm 1) can purchase the patent of the improved technology. If the use of the original technology is not in this scope, Firm 1 cannot purchase it, and should pay the royalty for the improved technology to Firm 2. We express the technical scope as b $(0 \le b \le 1)$, which is the probability that the technology Firm 2 uses is in the technical scope. The technical scope of the assign-back is considered to be large, when the original technology is essential or when the licensor (Firm 1) has significant bargaining power.

At the third stage, the licensor, Firm 1, offers the assigned price for the improved technology as s. The licensee, Firm 2, chooses whether to accept the offer (take-it or leave-it offer). If Firm 2 rejects the assign-back, Firm 2 can no longer create license contracts related to the original technology and its unit cost is c_0. Thus, as long as Firm 2's expected profit in accepting the assign-back is larger than the profit it will earn without the license contract, Firm 2 will accept the offer of the assigned price. Firm 2's profit without the license contract is

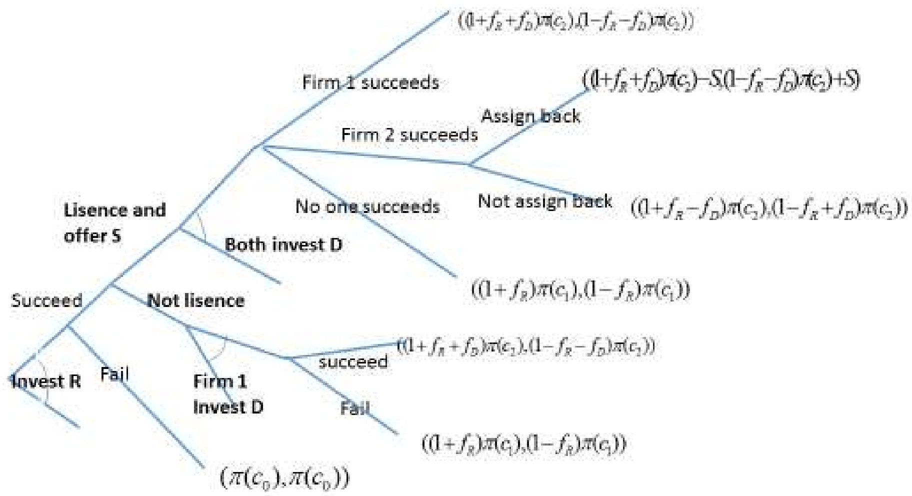
$$\overline{\Pi_2} = \Theta(\overline{D_1},0)\pi(c_0,c_2) + \{1-\Theta(\overline{D_1},0)\}\pi(c_0,c_1),$$

[4] An excessively high royalty is prohibited by the Antitrust Law and in general market sets the royalty at a reasonable level.

where $\overline{D_1}$ is set to maximize the profit of Firm 1 without the license contract,

$$\Theta(D_1,0)\ \pi(c_2,c_0)+(1-\Theta(D_1,0))\pi(c_1,c_0)-D_1.$$

Figure 1



At the fourth stage, both firms choose their investment in the improved technology, (D_1,D_2). When Firm 1 succeeds in both technologies, the profits of Firm 1 and Firm 2 are $((1+f_R+f_D)\pi(c_2),(1-f_R-f_D)\pi(c_2))$ and this case occurs with probability, θ_1.

The probability that Firm 2 succeeds in the improved technology, using the original technology in the technical scope of the assign-back, is $\theta_2 b$. In that case, Firm 1 purchases the patent of the improved technology at price, S, and Firm 2 pays the royalty of both technologies to Firm 1. Therefore the profits of both firms are $((1+f_R+f_D)\pi(c_2)-S,(1-f_R-f_D)\pi(c_2)+S))$.

In the same way, the probability that Firm 2 succeeds in the improved technology, using the original technology outside the technical scope of the grant-back is $\theta_2(1-b)$. The profits of both firms in that case are $((1+f_R-f_D)\pi(c_2),(1-f_R+f_D)\pi(c_2))$.

We assume that the total profit with a license is always higher than that without a license[5]. Thus,

$$2(\theta_1+\theta_2)\pi(c_2)+2(1-\theta_1-\theta_2)\pi(c_1)-D_1-D_2>\overline{\Pi_2}+\overline{\Pi_1}$$

is satisfied. In addition, we assume that they cannot include the level of investment in

[5] We will focus on the case in which the license contracts increase the total profit of the firms, because when the license contracts do not do so, the license contracts will not be made.

the license contract, and the equilibrium concept we adopt is a subgame perfect Nash equilibrium. The game tree is shown in Figure 1.

2.2 The first-best investment under the Cournot competition

Because the expected social welfare after obtaining the original technology is

$W(c_2)(\theta_1+\theta_2)+W(c_1)(1-\theta_1-\theta_2)-D_1-D_2$,

where $W(c_i)$ is the social welfare[6] when each firm produces at c_i in the Cournot equilibrium, the first-order condition for the best investment in the improved technology under the Cournot competition is

$$\{W(c_2)-W(c_1)\}(\Theta_{i,Di}+\Theta_{j,Di})-1=0 \qquad (i\neq j). \tag{1}$$

The first-order condition for the first-best investment in the original technology under the Cournot competition is

$$(\Gamma_{i,Ri}+\Gamma_{j,Ri})[(\theta_1+\theta_2)\{W(c_2)-W(c_1)\}+W(c_1)-W(c_0)]-1=0. \tag{2}$$

3. Equilibrium

Now, we solve this game backward.

At the fourth stage, both firms choose their investment for the improved technology, (D_1,D_2), independently, given the technical scope of the assign-back provision, b, and the assigned price of the improved technology, S. The expected profit of Firm 1 is

$$\Pi_1=\theta_1(1+f_R+f_D)\pi(c_2)+\theta_2 b\{(1+f_R+f_D)\pi(c_2)-S\}$$
$$+\theta_2(1-b)(1+f_R-f_D)\pi(c_2)+(1-\theta_1-\theta_2)(1+f_R)\pi(c_1)-D_1$$

The first-order condition of D_1 is

$$\Theta_{1,D1}\{(1+f_R+f_D)\pi(c_2)-(1+f_R)\pi(c_1)\}+\Theta_{2,D1}b\{2f_D\pi(c_2)-S\}$$
$$+\Theta_{2,D1}\{(1+f_R-f_D)\pi(c_2)-(1+f_R)\pi(c_1)\}-1=0 \tag{3}$$

[6] $W(c_i)$ consists of the profits of the two firms, $2\pi(c_i)$, and the consumer surplus when each firm produces the goods at c_i under the Cournot competition.

We rewrite equation (3) as $F(D_1, D_2, S) = 0$, and from the assumption on the probability function, the second-order condition, $\partial F / \partial D_1 = F_{D1} < 0$, is satisfied.

On the other hand, the expected profit of Firm 2 is

$$\Pi_2 = \theta_1 (1 - f_R - f_D)\pi(c_2) + \theta_2 b\{(1 - f_R - f_D)\pi(c_2) + S\}$$

$$+ \theta_2(1-b)(1 - f_R + f_D)\pi(c_2) + (1 - \theta_1 - \theta_2)(1 - f_R)\pi(c_1) - D_2$$

Therefore the first-order condition of D_2 is

$$\Theta_{1,D2}\{(1 - f_R - f_D)\pi(c_2) - (1 - f_R)\pi(c_1)\} - \Theta_{2,D2} b\{2 f_D \pi(c_2) - S\}$$

$$+ \Theta_{2,D2}\{(1 - f_R + f_D)\pi(c_2) - (1 - f_R)\pi(c_1)\} - 1 = 0 \quad . \qquad (4)$$

We rewrite equation (4) as $G(D_1, D_2, S) = 0$, and from the assumption on the probability function, the second-order condition, $\partial G / \partial D_2 = G_{D2} < 0$ is satisfied.

Proposition 1.

The investment in the improved technology in the equilibrium is smaller than the best investment under Cournot competition.

Proof

We can rewrite the equations (3) and (4) as follows,

$$\partial \Pi_1 / \partial D_1 = \Theta_{1,D1} A + \Theta_{2,D1} B - 1 = 0 \qquad (3')$$

$$\partial \Pi_2 / \partial D_2 = \Theta_{1,D2}\{2\pi(c_2) - 2\pi(c_1) - A\} + \Theta_{2,D2}\{2\pi(c_2) - 2\pi(c_1) - B\} - 1 = 0 \quad , \qquad (4')$$

where

$$A = (1 + f_R + f_D)\pi(c_2) - (1 + f_R)\pi(c_1),$$

$$B = b\{2 f_D \pi(c_2) - S\} + (1 + f_R - f_D)\pi(c_2) - (1 + f_R)\pi(c_1) \quad .$$

Comparing equations (3')(4') with equation (1), from $W(c_2) - W(c_1) > 2\{\pi(c_2) - \pi(c_1)\}$, D_1 and D_2, are smaller than the socially best option under Cournot competition. Q.E.D.

Under-investment in the improved technology occurs, because neither firm considers the positive effect on the profit of the other firm when it succeeds, and that on consumers' welfare. Therefore, an increase in the investment in the improved technology leads to an increase in the social welfare.

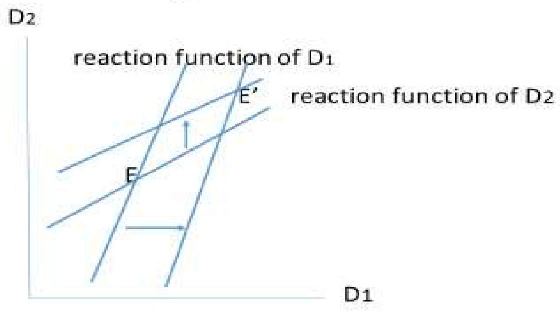
Lemma 1.

From the assumption on the probability function, the firms' investment in the technology, D_1 *and* D_2*, are strategic complements and the condition for the stability of the Nash equilibrium,* $|F_{D1}/F_{D2}|>|G_{D1}/G_{D2}|$*, is satisfied.*

Proof

The slope of the reaction function of Firm 1 is $dD_2/dD_1=-F_{D1}/F_{D2}$. From the second-order condition, F_{D1} is negative. From the assumption on the probability function, $F_{D2}>0$, we have $dD_2/dD_1>0$, which denotes a strategic compliment. In the same way, the slope of the reaction function of Firm 2 is $dD_2/dD_1>0$, because $G_{D1}>0$. The condition for the stability of the Nash equilibrium $|F_{D1}/F_{D2}|>|G_{D1}/G_{D2}|$ is satisfied from the assumption on the probability function. (Q.E.D)

Figure 2



When the investment in the improved technology, D_1 and D_2, are strategic complements, the reaction functions are upward sloping, as drawn in Figure 2. The investment in the improved technology in equilibrium can be expressed as $D_1^*(S)$ $D_2^*(S)$, depending on S, which is the assigned price of the improved technology.

An increase in the price of the assign-back, S, shifts the reaction function of $D_1^*(S)$ rightward, because the partial differential of equation (1) by S is $-\Theta_{2,D1}b>0$.

Using the same logic, the reaction function of D2 shifts upward by an increase in the assign-back price. Therefore the equilibrium shifts from E to E' by an increase in the price of the assign-back. Thus we obtain *Proposition 2.*

Proposition 2

An increase in the price of assign-back, S *, increases the investment in the improved technology of both firms, that is,* $dD_1^*(S)/dS > 0$*, and* $dD_2^*(S)/dS > 0$.

Proof

From the assumption, $F_{D1} < 0 < F_{D2}$, $G_{D2} < 0 < G_{D1}$, $G_S = b\Theta_{2,D2}$, and $F_S = -b\Theta_{2,D1} > 0$, we have $\dfrac{dD_1^*(S)}{dS} = \dfrac{F_{D2}G_S - G_{D2}F_S}{F_{D1}G_{D2} - F_{D2}G_{D1}} = \dfrac{b(F_{D2}\Theta_{2,D2} + G_{D2}\Theta_{2,D1})}{F_{D1}G_{D2} - F_{D2}G_{D1}}$.

From the assumption of $F_{D2} > 0$ and Lemma 1, we have $F_{D2}\Theta_{2,D2} + G_{D2}\Theta_{2,D1} > 0$ and $dD_1^*(S)/dS > 0$. In the same way, $\dfrac{dD_2^*(S)}{dS} = \dfrac{G_{D1}F_S - F_{D1}G_S}{F_{D1}G_{D2} - F_{D2}G_{D1}} = \dfrac{-b(G_{D1}\Theta_{2,D1} + F_{D1}\Theta_{2,D2})}{F_{D1}G_{D2} - F_{D2}G_{D1}}$.

From the assumption of $G_{D1} > 0$, we have $G_{D1}\Theta_{2,D1} + F_{D1}\Theta_{2,D2} < 0$ and $dD_2^*(S)/dS > 0$. Q.E.D.

Let us explain *Proposition 2* intuitively. When the price of the assign-back, S , is 0, Firm 1 would like to have Firm 2 succeed in the improved technology, because Firm 1 can use the improved the technology invented by Firm 2 for free. However, as the price of the assign-back increases, Firm 1 has more of an incentive to win the race in the improved technology in order to save the cost of the assign-back. Firm 2 also has more of an incentive to succeed in the improved technology by an increase in S.

At the third stage, Firm 1 chooses the price of the assign-back, S, considering the following conditions. The maximization problem of Firm 1 is

$$MAX_S \quad \Pi_1(D_1(S), D_2(S), S,)$$

s.t. $\Pi_1(D_1(S), D_2(S), S) \geq \overline{\Pi_1} = \{1 - \Theta(D_{1N}, 0)\}\pi(c_1, c_0) + \Theta(D_{1N}, 0)\pi(c_2, c_0) - D_{1N}$ (5)

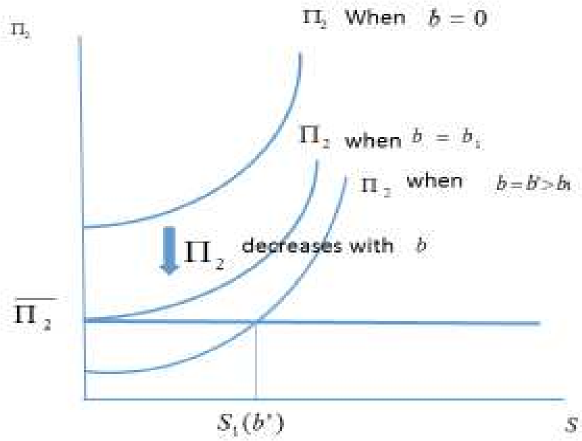
$$\Pi_2(D_2(S), D_1(S), S) \geq \overline{\Pi_2} = \{1 - \Theta(D_{1N}, 0)\}\pi(c_0, c_1) + \Theta(D_{1N}, 0)\pi(c_0, c_2), \qquad (6)$$

where D_{1N} is D_1 to maximize $\Pi_1 = \{1 - \Theta(D_1, 0)\}\pi(c_1, c_0) + \Theta(D_1, 0)\pi(c_2, c_0) - D_1$.

The first condition, equation (5), shows the incentive of Firm 1 to make the license contract with Firm 2. Firm 1 does not make the license contract, if the expected profit with the assign-back is lower than the profit when it engages in the research for the improved technology by itself, $\overline{\Pi_1}$. First, we assume that the first condition is satisfied, and then examine this condition later.

The second condition, equation (6), is to have Firm 2 participate in R&D for the improved technology. Firm 2 does not make the license contract, if its expected profit under the assign-back provision is lower than that without the license of the original technology.

Figure 3



In Figure 3, we show the relationship between the price of the assign-back, S, and Firm 2's profit, given the technical scope of the grant-back, b. An increase in S brings about an increase in the investment of the improved technology, which leads to an increase in Firm 2's profit. When $b=0$, the profit of Firm 2 under the assign-back is larger than that without the license contract, and the second condition is not binding. Therefore in this case, Firm 1 offers $S=0$, which Firm 2 will accept. As b increases, the profit of Firm 2 decreases and the profit curve shifts downward, as shown in Figure 3.

Let us define b to satisfy

$$\Pi_2(D_2(0), D_1(0),0) = \overline{\Pi_2} = \{1-\Theta(D_{1N},0)\}\pi(c_0,c_1)+\Theta(D_{1N},0)\pi(c_0,c_2)$$

as b_1. When $b=b_1$, Firm 2' s profit is zero at $S=0$, as shown in Figure 3. When b

becomes higher than b_1, say b', in Figure 3, the second condition (equation (6)) becomes binding, and Firm 2 will reject the offer, which gives him less profit than that without the license contract. Thus, when $b > b_1$, Firm 1 cannot but offer S' enough to give Firm 2 as much profit as that without the license.

Proposition 3

When $\Pi_1(D_1(S(b)), D_2(S(b)), S(b)) \geq \overline{\Pi_1}$ *is satisfied, that is, Firm 1 would like to make the license contract with Firm 2, the price of the assign-back in the equilibrium,* S^**, is ,*

If $b \leq b_1$, $S^* = 0$

If $b > b_1$, S^* *is the solution of*

$\Pi_2(D_2(S^*), D_1(S^*), S^*) = \overline{\Pi_2} = \{1 - \Theta(D_{1N}, 0)\}\pi(c_0, c_1) + \Theta(D_{1N}, 0)\pi(c_0, c_2)$

and increases with b.

Proof See Appendix 1.

Therefore, we can express the price of the assign-back chosen by Firm 1, given the technical scope of the assign-back, as $S(b)$.

Then, we consider those cases in which b_1 is large. In other words, in what cases is Firm 2 more likely to accept $S = 0$?

When Firm 2's profit without the license contract, $\{1 - \Theta(D_{1N}, 0)\}\pi(c_0, c_1) + \Theta(D_{1N}, 0)\pi(c_0, c_2)$ is relatively small, Firm 2 easily accepts zero as the price of assign-back. In this case b_1 is large. In other words, when $\pi(c_0, c_1)$ and $\pi(c_0, c_2)$ are small and $\Theta(D_{1N}, 0)$ is large, the price of the assign-back is likely to be zero. In other words, when the innovation sizes, $(c_0 - c_1)$ and $(c_0 - c_2)$ are large and Firm 1 can easily get the improved technology by itself, Firm 2 cannot get positive price for the assign-back.

Now, let us examine how the investments in the improved technology, D_1 and D_2, change with the technical scope, b.

Proposition 4

Suppose that $\Pi_1(D_1(S(b)), D_2(S(b)), S(b)) \geq \overline{\Pi_1}$ *is satisfied, that is, Firm 1 would like to make the license contract with Firm 2. In this case,* D_1 *and* D_2 *always decrease* *with* b*. If* $b > b_1$*, this effect is weakened by the assigned price that increases with* b*.*

Proof

The first-order condition for D_1 and D_2 can be rewritten as

$F(D_1, D_{2,}, S(b), b) = 0$ and $G(D_1, D_{2,}, S(b), b) = 0$

From the total differential of F and G, we get

$$\frac{dD_1^*}{db} = \frac{F_{D2}(G_S S_b + G_b) - G_{D2}(F_S S_b + F_b)}{F_{D1}G_{D2} - F_{D2}G_{D1}}.$$

In the same way, $\frac{dD_2^*}{db} = \frac{G_{D1}(F_S S_b + F_b) - F_{D1}(G_S S_b + G_b)}{F_{D1}G_{D2} - F_{D2}G_{D1}}$.

When $b \le b_1$, from $S_b = 0$, $G_b < F_b < 0$, $F_{D2} > 0$, $G_{D1} > 0$ and Lemma 1, we obtain

$$\frac{dD_1^*}{db} = \frac{F_{D2}G_b - G_{D2}F_b}{F_{D1}G_{D2} - F_{D2}G_{D1}} < 0 \text{ and } \frac{dD_2^*}{db} = \frac{G_{D1}F_b - F_{D1}G_b}{F_{D1}G_{D2} - F_{D2}G_{D1}} < 0$$

On the other hand, when $b > b_1$, we have $\frac{\partial S}{\partial b} = \frac{\theta_2\{2 f_D \pi(c_2) - S\}}{(\partial \Pi_2 / \partial D_1)(\partial D_1 / \partial S) + (\partial \Pi_2 / \partial S)}$

from *Proposition 2.*

From the proof of *Proposition 2,* $\partial \Pi_2 / \partial D_1 > 0$, $\partial D_1 / \partial S > 0$, and $\partial \Pi_2 / \partial S = \theta_2 b$, we get $(\partial \Pi_2 / \partial D_1)(\partial D_1 / \partial S) + (\partial \Pi_2 / \partial S) > \theta_2 b$. Thus, $S_b < \{2 f_D \pi(c_2) - S\} / b$.

From $G_S = \Theta_{2,D2} b$ and $G_b = -\Theta_{2,D2}\{2 f_D \pi(c_2) - S\}$, we get $G_S S_b + G_b < 0$.

From $F_S = -\Theta_{2,D1} b$ and $F_b = \Theta_{2,D1}\{2 f_D \pi(c_2) - S\}$, we get $F_S S_b + F_b < 0$.

Thus, $dD_1 / db < 0$ and $dD_{2,} / db < 0$. Q.E.D.

Next, we discuss the implication of *Proposition 4.* When $b \le b_1$, the price of the assign-back, S, is zero. An increase in b means that at the higher probability, Firm 1 can obtain the patent of the improved technology from Firm 2 for free. Thus, Firm 1 has less of an incentive to invest in the improved technology by an increase in b. Firm 2 also has less of an incentive, because a higher b means that Firm 2 cannot earn a profit with a higher probability, even though it succeeds in the innovation of the improved technology.

On the other hand, when $b > b_1$, Firm 2 can get S by the assign-back and S is increasing with b. By an increase in S, both Firm 1 and Firm 2 have more of an incentive to increase their investment in the improved technology, because Firm 1 would like to decrease the probability of success of Firm 2 and Firm 2 would like to earn a profit from the improved technology, S, with a higher probability. Thus the negative effects of b on investments are weakened by an increase in S.

Proposition 5

Suppose that $\Pi_1(D_1(S(b)), D_2(S(b)), S(b)) \geq \overline{\Pi_1}$ *is satisfied, that is, Firm 1 makes a license contract with Firm 2. In this case, if* $b \leq b_1$, Π_1 *increases, but* Π_2 *decreases with* b. *However when* $b > b_1$, Π_2 *is constant, but* Π_1 *decreases with* b.

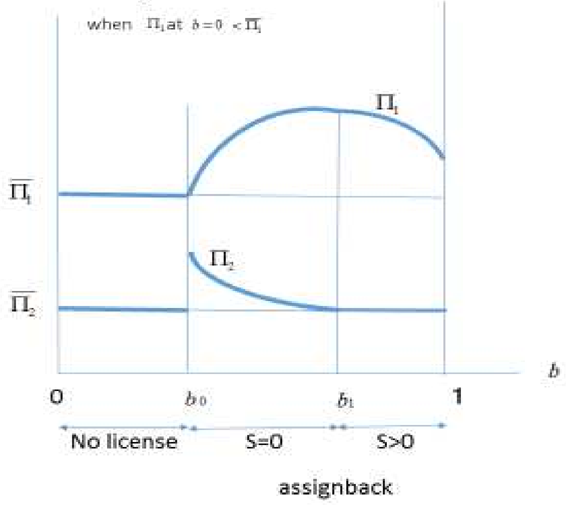
Proof See Appendix 2.

When $b \leq b_1$, there are two effects of increases in b on each profit. First, the probability that Firm 1 can use Firm 2's patent for free increases. Thus Firm 1's profit increases, while that of Firm 2 decreases. Second, an increase in b brings about a decrease in the investment of each firm for the improved technology, D_i, which brings about a decrease in the profit of each firm. Thus an increase in b means Firm 2's profit always decreases, but Firm 1's profit increases because the first effect is larger than the second effect. We show the relationship between the technical scope of the grant-back, b, and the profit of each firm in Figure 4.

When $b > b_1$, the profit of Firm 2 is constant at $\overline{\Pi_2}$ and there are three effects of an increase in b on Firm 1's profit, including the two effects mentioned in the case of $b \leq b_1$. The third effect occurs through the price of the assign-back. From Proposition 4, when $b > b_1$, an increase in b causes an increase in the price of the assign-back, which leads to a decrease of Firm 1's profit. Therefore, an increase in b decreases Firm 1's profit.

Next, we examine Firm 1's incentive to make license contracts. As stated in *Proposition 5, if* $b \leq b_1$, Π_1 increases with b, but if $b > b_1$, Π_1 decreases with b. When b=1, Firm 2's profit is equal to $\overline{\Pi_2}$. From the assumption that the license contract always increases the total profit of Firm 1 and Firm 2, Firm 1's profit when b=1 is larger than $\overline{\Pi_1}$. Thus, we obtain *Proposition 6.*

Figure 4



Proposition 6

If Firm 1's profit in equilibrium when $b=0$ *is higher than* $\overline{\Pi_1}$, *Firm 1 always makes a license contract with Firm 2. Otherwise, Firm 1 makes a license contract with Firm 2 if* $b \geq b_0$, *where* b_0 is b *satisfying*

$$\Pi_1(D_1(S(b)),D_2(S(b)),S(b),b) = \overline{\Pi_1} = \{1-\Theta(D_{1N},0)\}\pi(c_1,c_0)+\Theta(D_{1N},0)\pi(c_2,c_0)-D_{1N}.$$

Then, in which cases is b_0 large ? Here, large b_0 means that Firm 1's profit from engaging in the innovation of the improved technology, $\{1-\Theta(D_{1N},0)\}\pi(c_1,c_0)+\Theta(D_{1N},0)\pi(c_2,c_0)-D_{1N}$, is large. Thus when the sizes of the innovation, (c_0-c_1) and (c_0-c_2) are large and the probability of Firm 1's success in the improved technology by himself is high, b_0 is large, that is, Firm 1 is less likely to make a license contract with Firm 2.

Next, we consider the first stage, namely, the choice of the investment for the original technology, R_i and R_j. The expected profit of Firm i is

$$\Omega = \Gamma(R_i,R_j)\ \Pi_1 + \Gamma(R_j,R_i)\Pi_2 + \{1-\Gamma(R_i,R_j)-\Gamma(R_j,R_i)\}\ \pi(c_0,c_0) - R_i$$

The first-order condition is

$$\Gamma_{i,Ri}(\Pi_1-\pi(c_0,c_0))+\Gamma_{j,Ri}(\Pi_2-\pi(c_0,c_0))-1=0$$

Therefore, as the profit when the firm succeeds in the original technology, Π_1, increases and Π_2 decreases, the investment in the original technology increases.

Proposition 7

Assume that Firm 1 makes a license contract with Firm 2, that is, Firm 1's profit when $b=0$ is higher than $\overline{\Pi_1}$ or $b \geq b_0$. When $b \leq (>) b_1$, the investment in the original technology, R, increases (decreases) with b.

Proof

From *Proposition 6,* when $b \leq b_1$, Π_1 is increasing and Π_2 is decreasing with b. Thus the investment in the original technology increases with b. When $b > b_1$, Π_1 is decreasing and Π_2 is constant. Thus, the investment in the original technology always decreases with b. *Q.E.D.*

From *Proposition 4,* the investment in the improved technology decreases with an expansion of the technical scope of the grant-back. Therefore when $b \leq b_1$, by an expansion of the technical scope of the grant-back, there is a trade-off between the investment in the improved technology and that in the original technology. On the other hand, when $b > b_1$, both investments decrease by an expansion of the technical scope of the assign-back. Thus, we can conclude that the government should regulate an assign-back, when the technical scope of the assign-back is broad.

4. The technical scope chosen by the licensor

In the previous sections, the technical scope of the assign-back was assumed to be given as the characteristic of each technology. In this section, we change this assumption. Now, we assume that the technical scope of the assign-back is chosen by the licensor of the original technology at the timing of the license contract of the original technology at the second stage. After the licensor commits the technical scope of the assign-back, he offers a price for the assign-back. By this change of the assumption, we can analyze whether the licensor of the original technology would like to expand the technical scope of the assign-back by as much as possible.

Proposition 8

When Firm 1 can choose the technical scope of the assign-back at the second stage, *Firm 1 always makes a license contract with Firm 2 and sets* b_1 as the technical scope of the assign-back.

Proof

Because Firm 1's profit in the equilibrium when $b = b_1$ is higher than $\overline{\Pi_1}$, Firm 1 always makes a license contract with Firm 2, and offers b_1 to maximize Firm 1's profit.

Q.E.D.

We find that Firm 1 has no incentive to expand the technical scope of the assign-back because a broader technical scope than b_1 decreases the investment by both firms in the improved technology and decreases Firm 1's profit.

Proposition 9

The investment in the original technology always increases by allowing an assign-back, when Firm 1 can choose the technical scope of the assign-back at the second stage.

Proof

Prohibiting an assign-back means $b = 0$. Because the profit of Firm 1 in the case of $b = b_1$ is larger than that in the case of $b = 0$, and the profit of Firm 2 in the case of $b = b_1$ is smaller than that in the case of $b = 0$, from *Proposition 5,* the investment in the original technology when $b = b_1$ is higher than that when $b = 0$.

Q.E.D.

5. A Comparison between the assign-back and the free royalty provision

Our analysis can be applied easily to the case of a free royalty provision, where Firm 1 need not pay the royalty for the improved technology to Firm 2. Under the free royalty provision, when Firm 2 succeeds in the improved technology, using the original technology in the technical scope of the grant-back, Firm 1's profit is $(1+f_R)\pi(c_2,c_2)$ and Firm 2's profit is $(1-f_R)\pi(c_2,c_2)$. Without the free royalty provision, Firm 1's profit is $(1+f_R-f_D)\pi(c_2,c_2)$ and Firm 2's profit is

$(1-f_R+f_D)\pi(c_2,c_2)$.

To compare the effects on the investment in the improved technology between the assign-back and the free royalty provision, we compare the profit of each firm when Firm 2 succeeds in the improved technology, using the original technology in the technical scope for the cases of "without grant-back," "free royalty provision," "assign-back when $b < b_1, (S=0)$," and "assign-back when $b_1 \leq b, (S>0)$" in Table 1.

Table 1: The profits of Firm 1 and Firm 2 when Firm 2 succeeds in the improved, using the original technology in the technical scope

	Firm 1's profit	Firm 2's profit
without grant-back	$(1+f_R-f_D)\pi(c_2)$	$(1-f_R+f_D)\pi(c_2)$
free royalty provision	$(1+f_R)\pi(c_2)$	$(1-f_R)\pi(c_2)$
assign-back when $b<b_1, (S=0)$	$(1+f_R+f_D)\pi(c_2)$	$(1-f_R-f_D)\pi(c_2)$
assign-back when $b>b_1$, $S>0$	$(1+f_R+f_D)\pi(c_2)-S$	$(1-f_R-f_D)\pi(c_2)+S$

From the previous analysis, the smaller Firm 2's profit in the Table 1 becomes, the less Firm 2 has an incentive to invest in the improved technology. In addition, the larger Firm 1's profit in the Table 1 becomes, the less Firm 1 has an incentive to invest in the improved technology.

First, consider the sizes of the investment in the improved technology. When b, the technical scope of the grant-back, is small enough to make $f_D\pi(c_2) \geq S$, the investment by both firms in the improved technology is small in ascending order of "assign-back," "free royalty provision," and "without grant-back."

On the other hand, when the technical scope of the grant-back is large enough to satisfy $f_D\pi(c_2) < S \leq 2f_D\pi(c_2)$ [7], the investment by each firm in the improved technology is small in the order of "free royalty provision," "assign-back," and "without grant-back."

Next, we focus on the size of the investment in the original technology. As denoted in Proposition 7, in the case of the assign-back, as long as $b \leq b_1$, the investment in the original technology, R, increases with b. However, if $b > b_1$, the investment in the

[7] The patent holder of the original technology would not like to put in the assign-back condition if $S > 2f_D\pi(c_2)$. Thus, $S \leq 2f_D\pi(c_2)$ is always satisfied.

original technology decreases with b. On the other hand, in the case of the free royalty provision, the investment in the original technology, R, continues to increase, as long as Firm 2 accepts the free royalty provision. If b gets too large, Firm 2 would not like to accept the free royalty provision. So we cannot compare the size of the investment in the original technology between the assign-back and the free royalty provision.

The other difference between the free royalty provision and the assign-back is as follows. First, let us compare the size of b_0 between the assign-back and the free royalty provision, b_0, is the technical scope, at which point, Firm 1 starts to make a license with Firm 2. In other words, when $b < b_0$, Firm 1 engages in R&D for the improved technology by itself. Firm 1's profit with the free royalty provision is lower than that with the assign-back, because with the assign-back Firm 1 can obtain the property right of the improved technology for free. Thus, b_0 under the free royalty provision is larger than that under the assign-back. In other words, Firm 1 with the free royalty provision is more reluctant to make a license contract than in the case of the assign-back. In this sense, the assign-back enhances dissemination more than the free royalty provision does.

Second, under the free royalty provision, if the technical scope of the grant-back, b, is sufficiently broad, Firm 2 may reject the license contract with free royalty provision. In that case, only Firm 1 invests in the improved technology, which is not socially desirable. However, under the assign-back, if the technical scope of the grant-back, b, is broad, Firm 1 offers a sufficiently high price for the assign-back to guarantee the profit without the license contract to Firm 2. Thus, Firm 2 would like to make a license contract and invest in the improved technology. In this sense, the assign-back enhances the dissemination more than the free royalty provision does.

6. Analysis of the guidelines published by the European Union, the United States, and Japan

The guideline of Japan prohibits the grant-back in principle but an assign-back with an adequate assigned price is permitted. The European Union regulates grant-backs when the licensor of the original technology has a high market share in the product markets, and the United States focuseson the power in a relevant technology market and the incentive for innovation. In this section, we examine the significance of each regulation.

Before analyzing each regulation, we consider whether the government should prohibit all of the assign-backs. The situation in which the government prohibits all of the assign-backs corresponds to the case of $b=0$. When Firm 1's expected profit without the license contract is relatively high, that is, when $b_0 > 0$, Firm 1 chooses to engage in R&D for the improved technology itself, rather than making license contracts, if the government prohibits all assign-backs and sets $b = 0$. Thus, the prohibition of an assign-back and a grant-back may lead to Firm 1's non-disclosure and non-license of the original technology. Therefore, the prohibition of all grant-backs is not desirable.

According to the EU guideline, grant-backs between companies with high market power are prohibited. In other words, even if a grant-back decreases the incentive for innovation of the improved technology, it is permitted when the licensor and the licensee have a low market share. Even though the grant-back may create some loss in the market of the technology, the European Union focuses on the loss in the product market. The market of the technology should be distinguished from that of the products. In order to decrease the dead weight loss in the product market, the government should regulate the monopolistic action in the product market. However, to measure the loss in the technology market, the government should check the level of the investments. In that sense, the US regulation is desirable.

The US commission focuses on the case in which the licensor has high bargaining power in the technology market, because this licensor can expand the technical scope and raise the price of the assign-back. However, if a licensor with high bargaining power tries to expand the scope, many licensees will start decreasing their investment in the improved technology, which leads to a reduction in the profit of the licensor. If the technical scope of the grant-back is too broad, the innovator of the improved technology may quit the license contract. Thus, the licensor has an incentive not to expand the technical scope. Thus, the U.S. Commission need not be worried about the expansion of the technical scope of the grant-back by the licensor.

The regulation of Japan permits a grant-back where the price of the assign-back is sufficiently high. According to our results, an increase in the price of the assign-back increases investment in the improved technology, but it decreases investment in the original technology. Thus, if the government finds a serious reduction in the investment in the improved technology, and the improved technology contributes to increasing social welfare, the government should encourage the patent holder to purchase the patent of the improved technology at the sufficiently high price. However, this guidance will decrease the investment in the original technology. There is a trade-off between investment in the improved technology and that in the original technology. Thus, the government should judge which technology is more valuable to society in each case.

7. Conclusion

We examined the effects of an assign-back and free royalty provision on investments in the original technology and the improved technology using the game theoretic model, considering the technical scope of the assign-back, that is, the technical scope to apply the assign-back. This is high when most parts of the original technology are used to obtain the improved technology or when the licensor of the original technology has high bargaining power and requests the assign-back, even though the improved technology is not derived from the original technology.

We examined two cases. First, the technical scope of the assign-back is given as the characteristics of the technology and second, it is chosen and committed to by the patent holder of the original technology. In addition, we compared the effect of an assign-back with that of the free royalty provision, and analyzed the guidelines for grant-backs published by the European Union, the United States and Japan theoretically. As a result, we obtain the following five conclusions.

First, the government should not prohibit grant-backs, because these enhance the dissemination of the original technology. By the grant-back, the licensor's profit with the license contract increases and the licensor has an incentive to make a license contract.

Second, we clarified the effects of an expansion of the technical scope of the assign-back, which we express as the probability that the improved technology is applied to the assign-back. When the technical scope is small, the licensee will accept zero as the offer of the price of the assign-back. By expanding the technical scope, the investment in the improved technology decreases, but that in the original technology increases, because an expansion of the technical scope of the assign-back decreases the expected profit of the licensee, and the licensor can use the improved technology for free with a higher probability. However, when the technical scope of the grant-back is over a certain threshold level, the licensor must offer a positive price of the assign-back in order to have the licensee join in the license contract. In this case, an expansion of the technical scope decreases the investments of both firms in both technologies. Thus, the government should regulate an assign-back, when the technical scope of the assign-back is broad. In addition, an increase in the price of the assign-back mitigates the negative effects on the investment for the improved technology.

Third, we examined the case in which the technical scope of the grant-back is chosen by the licensor. The licensor of the original technology does not have an incentive to expand the technical scope of the grant-back as much as possible, because expanding the technical scope over the threshold level decreases the investment in the improved technology by both firms and reduces the licensor's profit.

Fourth, we compared the assign-back with the free royalty provision. As in the case of the free royalty provision, the expansion of the technical scope of the grant-back decreases investment in the improved technology, but increases that in the original technology. The main difference between the assign-back and the free royalty provision is that the assign-back enhances the dissemination more than the free royalty provision does. There are two reasons of this result. First, when the technical scope is small, the assign-back gives the licensor a greater incentive to make a license contract, because the assign-back gives the licensor a higher expected profit than the free royalty provision does. The second reason is that when the technical scope is large, the assign-back gives the licensee a greater incentive to join the license contract by raising the price of the assign-back.

Fifth, we discussed the guidelines published by the European Union, the United States, and Japan. The guideline of Japan basically prohibits grant-backs but permits assign-backs with a fair price. According to our result, prohibiting all grant-backs is not desirable and the assign-back with the fair price mitigates the problems with grant-backs, that is, a decrease the investment in the improved technology. The EU guideline prohibits a grant-back between companies with high market power in the product market. Even if the grant-back may create some losses in the market of the technology, such as a decrease in investment, the EU guideline focuses on the loss in the product market only. The market of the technology should be distinguished from that of the products. In order to decrease the dead-weight loss in the product market, the government should regulate the monopolistic action in the product market. However, to measure the loss in the technology market, the government should also check the level of the investments. In that sense, the US regulation is desirable.

As noted earlier, the US Commission focuses on the case in which the licensor has high power in the technology market, because this licensor with the high power can expand the technical scope and raise the price of the assign-back. However, according to our result, the licensor does not have an incentive to expand the technical scope as much as possible, because the expansion will decrease the licensor's profit, too.

Note that we do not examine cases in which there are multiple licensees. However, in that case, we can expect similar conclusions.

Appendix 1

Solving this problem by using a Lagrangian, from $\partial\Pi_1/\partial D_1 = 0$, we get

$$L = \Pi_1(D_1(S), D_2(S), S)$$
$$+\lambda\ [\Pi_2(D_2(S), D_1(S), S) - \{1-\Theta(D_{1N},0)\}\pi(c_0,c_1) - \Theta(D_{1N},0)\pi(c_0,c_2)]$$

$$\partial L/\partial S = (\partial\Pi_1/\partial D_2)\ (dD_2/dS) + \partial\Pi_1/\partial S + \lambda\ \{(\partial\Pi_2/\partial D_1)(dD_1/dS) + \partial\Pi_2/\partial S\} = 0$$

$$\lambda\ [\Pi_2(D_2(S), D_1(S), S) - \{1-\Theta(D_{1N},0)\}\pi(c_0,c_1) - \Theta(D_{1N},0)\pi(c_0,c_2)] = 0.$$

In order to get the sign of $\partial\Pi_i/\partial D_j$, we rewrite equations (3) and (4) into

$\Theta_{1,D1}\mathrm{A} + \Theta_{2,D1}B = 1$ and $\Theta_{1,D2}E + \Theta_{2,D2}F = 1$,

where A+E=B+F=$2\{\pi(c_2)-\pi(c_1)\}$. Thus we have

$$\partial\Pi_i/\partial D_j = \Theta_{1,D2}A + \Theta_{2,D2}B$$

$$= \Theta_{1,D2}[\{2(\pi(c_2)-\pi(c_1))\} - E] + \Theta_{2,D2}[\{2(\pi(c_2)-\pi(c_1))\} - F]$$

$$= 2\{\pi(c_2)-\pi(c_1)\}\ (\Theta_{1,D2} + \Theta_{2,D2}) - 1 > 0.$$

From $\partial D_i/\partial S > 0$ and $\partial\Pi_1/\partial S = -\partial\Pi_2/\partial S = -\theta_2 b < 0$, the equilibrium is

(I) S*=0, $\lambda = 0$

$$\Pi_2(D_2(0), D_1(0), 0) - \{1-\Theta\ (D_{1N}, 0)\}\pi(c_0, c_1) - \Theta(D_{1N}, 0)\pi(c_0, c_2) > 0$$

$$\Pi_1(D_1(0), D_2(0), 0) - \{1-\Theta(D_{1N}, 0)\}\pi(c_1, c_0) - \Theta(D_{1N}, 0)\pi(c_2, c_0) + D_{1N} \geq 0$$

(II) $S^* > 0$, $\lambda > 0$,

$$\Pi_2(D_2(S^*), D_1(S^*), S^*) - \{1-\Theta(D_{1N}, 0)\}\pi(c_0, c_1) - \Theta(D_{1N}, 0)\pi(c_0, c_2) = 0$$

$$\Pi_1(D_1(S^*), D_2(S^*), S^*) - \{1-\Theta\ (D_{1N}, 0)\}\pi(c_1, c_0) - \Theta\ (D_{1N}, 0)\pi(c_2, c_0) + D_{1N} \geq 0$$

$$\lambda = -\frac{(\partial\Pi_1/\partial D_2)(dD_2/dS) - \theta_2 b}{(\partial\Pi_2/\partial D_1)(dD_1/dS) + \theta_2 b}$$

When $b = 0$, λ is negative and equation (6), that is, the condition such that Firm 2 will invest for the improved technology is not binding. Thus equilibrium (I) is obtained. When $b > b_1$, equation (6) becomes binding and equilibrium (II) is obtained.

Next, we show the price of the assign back is increasing with b in the equilibrium II, where S>0 and Π_2 is constant. From

$d\Pi_2/db = (\partial\Pi_2/\partial D_2)(dD_2/dS)(dS/db) + (\partial\Pi_2/\partial D_1)(dD_1/dS)(dS/db) + (\partial\Pi_2/\partial S)(dS/db) + (\partial\Pi_2/\partial b) = 0$ and $\partial\Pi_2/\partial D_2 = 0$

we get

$(\partial\Pi_2/\partial D_1)(dD_1/dS)(dS/db) + (\partial\Pi_2/\partial S)(dS/db) = -\partial\Pi_2/\partial b$

$= \theta_2(2 f_D \pi(c_2) - S) > 0.$ From $(\partial\Pi_2/\partial D_1)(dD_1/dS) + (\partial\Pi_2/\partial S) > 0$, we get $\dfrac{dS}{db} > 0$.

Q.E.D.

Appendix 2

$d\Pi_1/db = (\partial\Pi_1/\partial D_2)(dD_2/db) + (\partial\Pi_1/\partial S)(dS/db) + (\partial\Pi_1/\partial b)$

$d\Pi_2/db = (\partial\Pi_2/\partial D_1)(dD_1/db) + (\partial\Pi_2/\partial S)(dS/db) + (\partial\Pi_2/\partial b)$

When $b \leq b_1$, $S = 0$, and $\partial S/\partial b = 0$. We obtain $dD_1/db < 0$ and $dD_2/db < 0$ from *Proposition 3*. From $\partial\Pi_1/\partial b = -\partial\Pi_2/\partial b = \theta_2\{2 f_D \pi(c_2) - S\}$, we get

$d\Pi_2/db = (\partial\Pi_2/\partial D_1)(dD_1/db) + (\partial\Pi_2/\partial b) < 0$

$d\Pi_1/db = (\partial\Pi_1/\partial D_2)(dD_2/db) + (\partial\Pi_1/\partial b)$

$$= \frac{\partial \Pi_1}{\partial D_2} (\frac{G_{D1}F_b - F_{D1}G_b}{F_{D1}G_{D2} - F_{D2}G_{D1}}) + \theta_2 \{2 f_D \pi(c_2) - S\}.$$

From $\partial L / \partial S = (\partial \Pi_1 / \partial D_2)(\partial D_2 / \partial S) + (\partial \Pi_1 / \partial S) < 0$ and Appendix 1,

$$0 < \frac{\partial \Pi_1}{\partial D_2} < -\frac{\partial \Pi_1 / \partial S}{\partial D_2 / \partial S} = -\frac{\theta_2 (F_{D1}G_{D2} - F_{D2}G_{D1})}{(G_{D1}\Theta_{2,D1} + F_{D1}\Theta_{2,D2})} \quad .$$

From the proof of Proposition 5,

we get $(\partial \Pi_1 / \partial D_2)(dD_2 / db) > -\frac{\theta_2 (G_{D1}F_b - F_{D1}G_b)}{(G_{D1}\Theta_{2,D1} + F_{D!1}\Theta_{2,D2})}$.

From $\partial F / \partial b = \Theta_{2,D1} \{2 f_D \pi(c_2) - S\}$ and $\partial G / \partial b = -\Theta_{2.D2} \{2 f_D \pi(c_2) - S\}$, we obtain

$$\frac{d\Pi_1}{db} > -\frac{\theta_2 (G_{D1}F_b - F_{D1}G_b)}{(G_{D1}\Theta_{2,D1} + F_{D1}\Theta_{2,D2})} + \theta_2 \{2 f_D \pi(c_2) - S\} = 0.$$

On the other hand when $S > 0$ and $b > b_1$, Π_2 is constant. However, Π_1 changes with b , that is,

$$d\Pi_1 / db = (\partial \Pi_1 / \partial D_2)(dD_2 / db) + (\partial \Pi_1 / \partial S)(\partial S / \partial b) + \partial \Pi_1 / \partial b$$
$$= (\partial \Pi_1 / \partial D_2)(dD_2 / db) - \theta_2 b (\partial S / \partial b) + \theta_2 \{2 f_D \pi(c_2) - S\}.$$

F

From $\partial L / \partial S = 0$, $\lambda > 0$, and $(\partial \Pi_1 / \partial D_2)(\partial D_2 / \partial S) + (\partial \Pi_1 / \partial S) > 0$, we get

$$\frac{\partial \Pi_1}{\partial D_2} \frac{dD_2}{db} < -\frac{(\partial \Pi_1 / \partial S)}{(\partial D_2 / \partial S)} \frac{dD_2}{db} = -\frac{\theta_2 [G_{D1} \{F_S (\partial S / \partial b) + F_b\} - F_D \{G_S (\partial S / \partial b) + G_b]}{(G_{D1}\Theta_{2,D1} + F_{D1}\Theta_{2,D2})}.$$

From $\partial F / \partial S = -\Theta_{2,D1} b$, $\partial G / \partial S = \Theta_{2,D2} b$, $\partial F / \partial b = \Theta_{2,D1} \{2 f_D \pi(c_2) - S\}$,

$\partial G / \partial b = -\Theta_{2,D2} \{2 f_D \pi(c_2) - S\}$, $\partial S / \partial b = \frac{\theta_2 \{2 f_D \pi(c_2) - S\}}{(\partial \Pi_2 / \partial D_1)(\partial D_1 / \partial S) + (\partial \Pi_2 / \partial S)}$, we obtain

$$\frac{d\Pi_1}{db} < -\frac{\theta_2 \{G_{D1}(\partial F / \partial S) - F_{D1}(\partial G / \partial S)\} \frac{\partial S}{\partial b} + \theta_2 \{G_{D1}(\partial F / \partial b) - F_{D1}(\partial G / \partial b)\}}{(G_{D1}\Theta_{2,D1} + F_{D1}\Theta_{2,D2})}$$
$$- \theta_2 b (\partial S / \partial b) + \theta_2 \{2 f_D \pi(c_2) - S\} = 0.$$

Q.E.D.

References

Choi Jay Pil (2002) "A Dynamic Analysis Of Licensing: The "Boomerang" Effect And Grantback Clauses" International Economic Review Vol.43 No.3 August pp.803-829.

Denicolo Vincenzo (2000) "Two-Stage Patent Races and Patent Policy", *The RAND Journal of Economics,* Vol.31, No.3 Autumn pp.488-501.

European Commission (2014) "Antitrust: Commission adopts revised competition regime for technology transfer agreements – frequently asked questions" in European Commission Press Release Database
http://europa.eu/rapid/press-release_MEMO-14-208_en.htm(3/25/2017).

Green, J. and S. Scotchmer (1995) "On the Division of Profit in Sequential Innovation" *RAND Journal of Economics,* Vol.26, No.1 Spring pp.20-33.

Hatanaka, K. (2012a) "Economic Analysis of Grant-back Condition" (in Japanese) Competition policy research center, Discussion Paper Series, 56-J.

Hatanaka K (2012b) "Should Grant-Back Provision In License Contract Be Prohibited?" Conference Proceedings of Advances In Business-Related Scientific Research Conference.

Japan Fair Trade Commision (2007) "Antitrust Guidelines for licensing the intellectual property" (in Japanese) http://www.jftc.go.jp/dk/guideline/unyoukijun/chitekizaisan.html

Lerner, Strojwas and Tirole (2007) "The Design of Patent Pools: The Determinants of Licensing Rules" RAND Journal of Economics Vol.38, No.3 pp.610-625.

Leone Maria Isabella and Reichstein Toke (2012) "Licensing-in Fosters Rapid Invention! The Effect of the Grant-back Clause and Technological Unfamiliarity" Strategic Management Journal Vol.33 pp.965-985.

.

Scotchmer (1991) "Standing on the shoulders of Giants: Cumulative Research and the Patent Law" *Journal of Economic Perspectives,* Vol.5, No.1, pp.29-41

U.S. Department of Justice and Federal Trade Commission (1995)
"Antitrust Guidelines for licensing the intellectual property"
https://www.justice.gov/atr/archived-1995-antitrust-guidelines-licensing-intellectual-property
(03/25/2017).