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Property Rights and Planned Obsolescence*

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We examine how varying the property rights affects the adoption of technologies and the compatibility between products with demand side and supply side economies of scale. In this environment, we obtain the following results. First, the social welfare is maximized by having all consumers use the same technology in the second period. Second, strong property rights may induce the dominant firm to introduce socially inefficient compatible technologies. Third, weak property rights may accelerate planned obsolescence. Finally, under weak property rights, openness of forward compatibility may prevent monopolist from implementing planned obsolescence.

Keywords : Property Rights, Planned Obsolescence, Forward Compatibility

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I . Introduction

Recently there is a policy debate over the compatibility between Microsoft's Windows and independent software in South Korea. South Korean competitors complained about Microsoft's practice of bundling extra programs with its Windows operating system. The complaints dealt specifically with the inclusion of the Windows instant messenger system, which allows people on different computers to converse in real time, and with the Windows Media Player, which plays sound and video. On February 24, 2006, the South Korean Fair Trade commission (KFTC) decided that Microsoft must now sell two versions of Windows in South Korea—one that includes competitors' programs, and one without them.[1] In addition, it decided that Microsoft should open the information necessary for competitors' compatibility with Microsoft operating system. This constraints Microsoft's property rights of compatibility. In relation to this, we examine how varying the property rights affects the adoption of technologies and the compatibility choices between products with network externalities.[2] We analyze them in terms of three property rights, as follows. First, strong property rights mean that if the monopolist owns technology A in the first period, the firm controls all of the property rights to given technology A not only in the first period but also in the second period. Second, contrary to this, weak property rights mean that once technology A is adopted in the first period, protection of the property rights is not extended to the second period. Thus, competitors can either pirate product A or provide a perfect substitute for product A. This leads to the price of product A being equal to marginal cost. Finally, we consider a third

1) The European Union's antitrust officials, saying that Microsoft had abused its monopoly in computer operating systems, in 2004 also ordered the company to offer a version of Windows stripped of its music and video player to allow rivals access to the ubiquitous Windows desktop. Microsoft is appealing the decision.

2) Consumers' utilities are said to exhibit network externalities if the utility of each consumer increases with an increase in total number of consumers purchasing the same or a compatible product.

way, in which not only the property rights of the old product but also the compatibility technology between old and new products is opened to everybody. We divide the compatibility into backward and forward compatibility,[3] then show that in the absence of a forward compatibility cost, this third way prevents the dominant firm not only from implementing planned obsolescence but also from providing degraded goods in the second period.

Before proceeding, we compare our analysis with related works. Katz and Shapiro (1986) considered a two-period model characterized by network externalities where two competing and incompatible technologies are each available in both periods. They investigated which technology is adopted under a variety of assumptions concerning the specification of property rights. By investigating a variant of the Katz and Shapiro model, which is characterized by a single-monopoly product, Waldman (1993) analyzed the monopolist's incentive to introduce new products too frequently, which is so-called planned obsolescence.

This paper is an extension of Katz and Shapiro (1986), Waldman (1993), and Choi (1994). However, there are a few differences between this paper and theirs. First, while the first two assumed incompatibility between old and new technologies, we consider the forward and backward compatibility between two technologies. Moreover, the dominant firm can decide whether to provide compatibility. Second, we separate the property rights of forward compatibility from those for emerging technology B. This pattern of property rights is different from Katz and Shapiro (1986). Third, compatibility choice was considered in Choi (1994). However, it did not distinguish compatibility into forward and backward compatibility in that analysis. Furthermore, it did not investigate the compatible choices in this property rights context.[4] Finally, we suppose that there is no marginal

3) According to Choi (1997), forward (backward) compatibility is defined as the ability of the old (new) product to subscribe to the benefit of the new (old) product network.

4) Lee (2006) and Hahn (2004) analyzed how backward compatibility, forward compatibility, and two-way compatibility respectively affect a firm's profit. However,

cost producing product, but a development cost of innovation. As noted by Shy (2001), information goods are characterized by having a large fixed and sunk production cost and a relatively low marginal cost since the cost of reproducing and distributing an additional is very low. For example, the production of software requires an investment in development and a negligible marginal cost. More explicitly, our model is related to the context of Boldrin and Levin (2005). They pointed out that most of the cost of writing software is not in the observation that it might be nice to justify text or in the algorithms for spacing lines, but rather in the detailed implementation and debugging of computer code. In this respect, the dominant firm that is a first-mover may not have a large development cost. Contrary to the first mover, the second mover's development cost is more expensive than that of the first because the single most difficult task faced by the developer is to provide compatible formatting capability with the first mover's software. We consider this situation in our model. Had the (potential) competitors benefited from the work done by the first in developing their detailed computer code, this substantial cost would have been avoided. In this regard, we investigate whether it is socially desirable to weaken the property rights of the first mover or not. Furthermore, from a social welfare point, we study which property rights are opened to competitors.

In the following section, we outline our model, which is a variant of that of Waldman (1993). Next, in Section 3, we study the pattern of adoption that would be induced if a social planner chose technologies. The bulk of analysis is presented in Section 4, where we describe market equilibriums for several different patterns of property rights and compare market outcomes with the socially optimal ones. Next, section 5 discusses the conclusions of this model and the directions in which to extend the analysis.

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the main distinction is that they did not investigate the compatible choices in this property rights context. More explicitly, they did not allow for planned obsolescence, which is the central concern of the present paper.

Ⅱ. The Model

There is a dominant producer who controls the property rights to a given technology. In the first period, the producer has to access to technology A, which is characterized by fixed cost K_A and output that is perfectly durable. In the second period, the firm gains access to a competing technology B that has fixed cost K_B. In the second period, there is forward (backward) compatibility technology, which has a constant marginal cost c_f (c_b) per unit. Assume that compatibility cost is smaller than per-unit network externalities between technologies (N), i.e., $0 \leq c_f, c_b < N$.

The demand side of the model is as follows. There are N identical individuals in group 1 who are present in the market in both periods. In each period, a group 1 consumer consumes either zero units or one unit of output. The total benefit that a consumer derives from a unit of output in a particular period depends on the total number of compatible units consumed in that period. To be specific, if an individual consumes a unit of technology k, $k=A, B$ in the period j (where $j=1,2$), then it receives a gross benefit equal to $V_k+N_k^j$, where V_k is stand-alone benefits of product k and N_k^j is the total number of consumers who use technology k in period j. Assuming that $N(V_A+N)>K_A$, we guarantee that a dominant firm supplies technology A in the period 1. It is also is assumed that there is no discounting. There are also N identical individuals in group 2, where group 2 is identical to group 1 except that group 2 individuals are only present in the market in the second period.

Notice that our model assumes that if de facto standardization is achieved as new technology, there are no network externalities and backward compatibility cost between old technology and new technology. However, in the case of word processors, if a firm makes new products read and write files in the old format, there will be some network externalities and backward compatibility cost between old technology and new technology. For convenience, we ignore this possibility.

As noted by Ellison and Fudenberg (2000), consumers' purchasing decisions, given announced prices, resembles a coordination game and can have multiple equilibriums. We assume that purchase decisions are made as if consumers in the same group act as though they were a single buyer, which is equivalent to selecting the continuation equilibrium that is best for them. And this is a full information model.

Suppose that all group 1 consumers buy good A in the first period. The possible cases, according to a combination of pricing and compatible choices, area as follows.

- AA (Standardization by old technology) : Technology A is employed in both periods. In this case, both groups consume A.
- BB (Standardization by new technology) : The technology is switched to B in the second period. In this case, both groups consume B.

In the above two cases, consumers achieve de facto standardization by having all consumers purchase the same technology. They enjoy the full benefits of network externalities. There are other ways in which compatibility may be achieved. Even products utilizing different technologies may be designed to work with one another, as follows.

- TC (Two-way Compatibility case) : Technologies A and B are employed. In addition to these, backward compatibility and forward compatibility are provided. Henceforth, we call product A equipped with forward compatibility "upgrade product" (A_U). In this case, group 1 consumes A_U and group 2 consumes B equipped with backward compatibility.[5)]
- BC (Backward Compatibility case) : Technologies A and B are employed. Unlike case TC, only backward compatibility is provided. In this case, group 1 consumes A and group 2 consumes B equipped with backward compatibility.
- FC (Forward Compatibility case) : Technologies A and B are employed. Unlike case TC, only forward compatibility is provided. In this case,

5) Because the group 1 consumers who purchased in the first period have relative low valuation for product B, we easily prove that there is no optimal case in which group 1 consumes B and group 2 consumes A.

group 1 consumes A_U and group 2 consumes B.

- IC (Incompatibility case) : Technologies A and B are employed, but they are incompatible with each other. In this case, group 1 consumes A and group 2 consumes B.

However, it is easy to prove that case FC and case IC cannot be the optimal solution for both social welfare maximization and dominant firm's profit maximization.[6] Hence, for optimization, it is sufficient to consider case AA, BB, TC, and BC.

We now examine how varying the property rights affects the adoption of technologies and compatibility of products with network externalities. We analyze them under three different property rights as follows. First, strong property rights mean that if the dominant firm owns technology A in the first periods, the firm controls all the property rights to given technology A not only in the first period but also in the second period. Second, contrary to this, weak property rights mean that once technology A is adopted, protection of the property rights is not extended to the second period. Finally, we consider the third way : not only the property rights of the old product but also forward compatibility technology are opened to everybody.

Ⅲ. First-best Adoption

We now turn to an analysis of the socially optimum choices for the technologies. We take total surplus for our welfare measure. Assuming that all group 1 consumers bought good A, we focus on the second period welfare. Let W_i (where i = AA, BB, TC, BC) denote the total surplus level corresponding to case i.

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6) Hahn (2004) showed that if a firm has a committing power to forward compatibility in the first period, then FC case can be an optimal solution. See Hahn. However, as mentioned below, the firm cannot commit to its second-period technology in the first period.

We first consider the cases where the social planner chooses to provide technology A and B in the second period. Then, W_i (where i = TC and BC) is at most

$N(V_A+2N)+N(V_B+2N)-K_B$, which is denoted by W_{AB}^* because there are compatible costs.

$$W_{AA}=N(V_A+2N)+N(V_A+2N),$$
$$W_{BB}=N(V_B+2N)+N(V_B+2N)-K_B.$$

If $V_A+2N > V_B+2N$, $W_{AA} > W_{AB}^*$ for all $K_B > 0$. Otherwise, $W_{BB} > W_{AB}^*$.

Therefore, TC and BC are not considered for the social optimum. When the two relevant cases, which AA and BB, are compared, we derive the following Proposition 1.

Proposition 1 : Social welfare is maximized by having all consumers use the same technology in the second period; that is, a social planner provides technology B (A) with both groups if and only if $W_{BB} > (<) W_{AA}$ if and only if $2\Delta VN > (<) K_B$, where ΔV is the differences in the stand-alone value for new product $(V_B - V_A)$.[7] Let $\overline{K_B}$ denote the critical fixed cost , i.e., $2N\Delta V$.

We have the following implications of Proposition 1. First, if $\Delta V < 0$, the social planner does not adopt technology B but continues to provide technology A in both periods. Second, contrary to the standard literature, our model has supply side economies of scale because of a sunk cost. Hence, there are more tendencies toward de facto standardization. Finally, considering that the dominant firm has strong property rights, it sells its output and has the ability to commit to its second-period technology in the first period. In the second period, because it can charge a lower price to those individuals who trade in an old unit, it has the ability to per-

7) Notice that if the stand-alone value for product B is non-negative, i.e., $V_B \geq 0$, then $\Delta V \geq -V_A$. For simplicity, assuming that V_A is sufficiently large, we neglect it henceforth.

fectly price discriminate. Hence, we easily prove that the committing firm attains socially efficient results.

Ⅵ. Non-commitment Dominant Firm

Now, we consider what happens when the monopolist cannot commit to its second-period technology in the first period. In this case, when period 2 arrives, the dominant firm must decide whether to choose one of the above-mentioned technology cases.

1. Strong Property Rights

We first show consumers' response to given prices. Let p_{ik}^{j} denote the price charged to a group i consumer who uses product k in period j. Now we find out the maximizing profit in each case. In this case, three cases of equilibriums are possible. At first, we find out the optimal prices and profits for each case. In case AA, it is easily seen that the maximum price charged to a group 2 consumer is $p_{2A}^{2} = V_A + 2N$. Therefore, the profit in the second period from this case is given by $\Pi_{AA} = (V_A + 2N)N$.

Now we find out the firm's optimal choices of technologies and the optimal profits for the other cases. Suppose that each group coordinates on the equilibrium that is best for it, that is, each coordinates on the reluctant rule.[8] At first, we investigate case BB. In this case, the dominant firm switches to B and sets the price for consumers, offering a trade-in low enough that all group 1 consumers purchase product B in the second period. The Lemma 1 summarizes the results.

Lemma 1

(a) In order to extract higher surplus from group 1, the firm will try to

8) For more detailed discussion and examples of the reluctant rule, refer to Appendix or to Ellison and Fudenberg (2000).

devalue product A. Therefore, the firm does not provide forward compatibility. However, the firm provides backward compatibility for product B.

(b) If the firm sets the prices $p_{1B}^2 = \Delta V + N$ and $p_{2B}^2 = V_B + 2N$, all consumers purchase product B. Thus, it makes technology B de facto standardization by having all consumers purchase product B. Thus, cost for backward compatibility is not incurred.

(c) The profit in the second period from this case is given by

$$\Pi_{BB} = (\Delta V + N)N + (V_B + 2N)N - K_B.$$

Proof. See Appendix. ■

Remark. Since p_{1B}^2 cannot have a negative value, henceforth we assume that $\Delta V \geq -N$.

Next, we consider the cases in which technologies A and B are employed in the second period, i.e., TC and BC. In case TC, the dominant firm sets the price (p_u) for consumers, offering an upgrade product A_u priced low enough that all group 1 consumers purchase a unit A_u in the second period. Lemma 2 summarizes the results.

Lemma 2

(a) If the dominant firm chooses to provide technologies A and B in the second period, case BC is dominated by case TC. Thus, the firm can increase profit by providing not only backward compatibility but also forward compatibility.

(b) Assuming $N > c_f$, the firm increases its profit $(N > c_f)N$ by supplying upgrade product at price $p_u = N$.[9] And it sets the price $p_{2B}^2 = V_B + 2N$.

(c) The profit in the second period in this case is given by

9) We know that if the firm cannot provide an upgrade product, it cannot obtain extra profit from group 1 consumers in the second period.

$$\Pi_{TC}=(N-f)N+(V_B+2N-b)N-K_B.$$

Proof. See Appendix. ■

From Lemma 2, we know that for solving the firm's maximization, it is sufficient to consider cases AA, BB, and TC. We first analyze the case in which product B has an improvement in stand-alone value, i.e., $\Delta V>0$. Next, we analyze the case in which product B has a degradation of stand-alone value, i.e., $\Delta V<0$.

In order to determine the dominant firm's decision, we must compare the firm's profit. Since $\Delta V>0$, $\Pi_{BB}-\Pi_{TC}=(\Delta V+c_b+c_f)N>0$. Therefore, maximizing profit, the firm does not consider case TC, in which it adopts both technologies and compatibility technology. Therefore, in order to derive the firm's optimal policy, it is sufficient to compare Π_{BB} with Π_{AA}. Thus, we have

$$\Pi_{BB}-\Pi_{AA}=(2\Delta V+N)N-K_B.$$

Therefore, the dominant firm provides technology B (A) with both groups if and only if $\Pi_{BB}>(<)\Pi_{AA}$ if and only if $(2\Delta V+N)N>(<)K_B$. Let denote the critical fixed cost $(2\Delta V+N)N)$ by $\overline{K_B^s}$. A comparison $\overline{K_B^s}$ with $\overline{K_B}$ yields that there are parameterizations where the firm switches, even though it is socially-efficient for it to remain with technology A. If $(2\Delta V+N)N>K_B>2\Delta VN$, then planned obsolescence happens.

We consider the case in which there is technology B in the second period that can make a degraded product by reducing the stand-alone value of the original product. In this case, from Proposition 1, the social planner does not adopt this technology in the second period and continues to retain technology A. Now we analyze whether the dominant firm adopts technology B or not. We investigate the two possible cases. The first is that the firm adopts inferior technology B as de facto standardization. This case holds if the following inequalities are satisfied.

$$\Pi_{BB}-\Pi_{TC}=(V_B-V_A+c_b+c_f)N>0, \quad (1)$$

$$\Pi_{BB}-\Pi_{AA}=(2V_B-2V_A+N)N-K_B>0. \quad (2)$$

From (1), we get $\Delta V>-c_b-c_f$. Since $K_B>0$, we have $\Delta V>-\frac{N}{2}$ from (2). Therefore, to hold this case, it is necessary that $0>\Delta V>\max[-\frac{N}{2}, -c_b-c_f]$.

Notice that if c_b and c_f are negligible, this case does not happen. This result is contrary to that of Waldman (1994); that is, the monopolist switches to inferior technology B and makes it de facto standard. The reason is that since our model considers forward compatibility, the firm can provide an upgrade product with forward compatibility for group 1 and gain more profit than with non-forward compatibility. Therefore, contrary to his model assuming incompatible technology, case TC dominates case AA. Second, we may have a more interesting case; that is, the firm adopts inferior technology B and uses compatible technology between A and B. This case holds if the following inequalities are satisfied :

$$\Pi_{BB}-\Pi_{TC}=(\Delta V+c_b+c_f)N<0, \quad (3)$$

$$\Pi_{TC}-\Pi_{AA}=(\Delta V+N-c_b-c_f)N-K_B>0. \quad (4)$$

From (3), we have $\Delta V<-c_b-c_f$. Since $K_B>0$, from (4) we have $\Delta V>-N+c_b+c_f$.

Therefore, to hold this case, it is necessary that $-c_b-c_f>\Delta V>-N+c_b+c_f$. If upgrade product A_U is forward-compatible with B, group 1 consumers are willing to pay the difference in network externalities (N) for an upgrade. The fear of being isolated from group 2 forces group 1 consumers to pay that amount. In particular, if the firm accesses to degradation technology with a sufficiently small fixed cost such that $(\Delta V+N-c_b-c_f)>K_B$ and a negligible compatibility cost between A and B, this case would occur. This can arise if the surplus extraction gain for group 1 due to network externalities is large enough to compensate for costs from introduction of degraded product B. Proposition 2 summarizes the discussion of a strong property rights case.

Proposition 2 : The dominant firm's incentive to introduce a new product that makes the old unit obsolete is too high; that is, the firm will have an incentive to practice planned obsolescence. Even though a new product is inferior to an old product, if the dominant firm accesses degradation technology and compatible technology with zero cost, strong property rights induce the dominant firm not to introduce technology B as de facto standardization, but to use both technologies and compatible technologies.

As pointed out in Waldman (1993), the basic reason behind Proposition 2 is that the dominant firm in such a setting faces a time-inconsistency problem; i.e., the firm's actual technology choice in the second period is different from the choice it would make if it could commit its second-period technology in the first period. Under strong property rights, as mentioned above, when the dominant firm has the ability to commit to its second period technology in the first period, the firm has the ability to practice perfect price discrimination. However, without credible commitment devices the firm does not internalize in the second period how its second period behavior affects the value of products it previously sold. In this case, the firm's private incentive to behave in a manner that lowers that value is too high. However, notice that the second period value of the previously sold products affects the price the firm initially receives for products. Considering this fact, the non-optimal incentive it faces in the second period can serve to lower its own profit as well as social welfare.

2. Weak Property Rights

Under weak property rights, we assume that competitors can either pirate product A or provide a perfect substitute for product A at the same marginal cost, at which it was originally produced, in the second period. Therefore, the price for product A will lead to a marginal cost equal to "0". Now we can derive the profits in the following three cases. First, in case AA, it is clear that the maximum price charged to a group 2 con-

sumer is $p_{2A}^2 = 0$. Therefore, the profit in the second period from this case is given by $\Pi_{AA} = 0$.

Second, in case BB, the dominant firm switches to B and sets the price for the consumers, offering a trade-in low enough that all group 1 consumers purchase unit B in the second period. We can write incentive constraints of both groups as follows.

$$V_B + 2N - p_{iB}^2 \geq V_A + N \text{ for all } i = 1, 2.$$

Because of an imitated or pirated product, group 2 consumers can purchase product A at price "0." Therefore, group 1 and group 2 have the same incentive constraint. Therefore, the profit in the second period from this case is given by

$$\Pi_{BB} = (\Delta V + N)2N - K_B.$$

Finally, we consider the cases in which the firm chooses to provide technologies A and B in the second period. In these cases, the dominant firm privately owns forward compatibility technology. The firm supplies an upgrade version only to group 1 and new product B to group 2.[10)]

In this case, incentive constraints for group 1 are given by

$$V_A + 2N - p_u \geq V_A + N, \tag{5}$$

$$V_A + 2N - p_u \geq V_B + 2N - p_{2B}^2. \tag{6}$$

If inequality (5) does not hold, a group 1 consumer would keep product A, and if (6) does not hold, it would consume product B.

We can write incentive constraint of group 2 as follows.

$$V_B + 2N - p_{2B}^2 \geq V_A + 2N. \tag{7}$$

If inequality (7) does not hold, a group 2 consumer purchases product A at price 0 from competitive firms. Now we investigate the prices that

10) As with strong property rights, we can easily prove that the profit-maximizing firm provides backward compatibility.

maximize the profit, satisfying the above constraints. It is obvious that the price p_{2B}^2 binding constraint (7) maximizes the firm's profit.[11] So $p_{2B}^2 = \max[\Delta V, 0]$. From (6), we have $p_u = 0$. Therefore, since $c_f > 0$, the dominant firm does not provide the upgrade product with forward compatibility for group 1. The reason why the result holds is as follows: Because group 2 consumers can purchase product A from competitors and behave by reluctant rule, group 2 consumers are, at most, willing to pay the differences in stand-alone benefits (ΔV) for product B. Notice that this value is lower than the price under strong property rights. However, for group 1 consumers who can purchase product B at the same price, group 1 consumers are not willing to pay a positive price for the upgrade product. Therefore, contrary to strong property rights, case TC is dominated by case BC. Thus, under weak property right, dominant firms cannot increase profit by providing forward compatibility. Therefore, the maximal profit in the second period from these cases is given by

$$\text{If } \Delta V \geq 0,\ \Pi_{BC} = (V_B - V_A - c_b)N - K_B.$$

Otherwise, the firm does not consider case BC.

Now, we first analyze the case in which product B has an improvement of stand-alone value, i.e., $\Delta V > 0$. Next, we analyze the case in which product B has a degradation of stand-alone value, i.e., $\Delta V > 0$. To determine the dominant firm decision, we must compare the firm's profit. Since $\Delta V > 0$, $\Pi_{BB} - \Pi_{BC} = (\Delta V + 2N + b)N > 0$. Therefore, in order to maximize profit, the firm does not consider case BC, and to derive the firm's optimal policy, it suffices to compare Π_{BB} with Π_{AA}. In this case, since $\Pi_{BB} - \Pi_{AA} = \Pi_{BB} \geq 0$, technology B is adopted if and only if

$$\Pi_{BB} = (V_B + N - V_A)2N - K_B = (2\Delta V + 2N)N - K_B \geq 0.$$

Let the critical fixed cost $(2\Delta V + 2N)N$ be denoted by $\overline{K}_B^w$. We compare

11) Suppose that it is not. The firm increases the price of product B, providing group 2 with satisfying constraints. Therefore, we obtain a contradiction.

the monopolist's incentives in adopting new technology under one property right with the same under others. At first, a comparison $\overline{K}_B^w$ with $\overline{K}_B$ yields that there are parameterizations where the firm switches, even though it is socially-efficient for it to remain with technology A. Since $\overline{K}_B^w - \overline{K}_B = 2N^2 > 0$, there exist cases where planned obsolescence happens, that is, $(2\Delta V + 2N)N = \overline{K}_B^w > K_B > \overline{K_B} = 2\Delta VN$. Next, a comparison $\overline{K}_B^w$ with $\overline{K}_B^s$ yields that there are parameterizations where the firm under weak property rights switches even though, under strong property rights, it remains with technology A. Since $\overline{K}_B^w - \overline{K}_B^s = N^2 > 0$, there exists the fixed cost interval satisfying the above condition, that is, $(2\Delta V + 2N)N = \overline{K}_B^w > \overline{K}_B^s = (2\Delta V + N)N$. Therefore, weak property rights may accelerate planned obsolescence more than strong property rights do.

Here we analyze the case in which product B has degradation of stand-alone value, i.e., $\Delta V < 0$. We consider the case in which there is technology B in the second period that can make a degraded product by reducing the stand-alone value of the original product. As mentioned above, under weak property rights, the dominant firm cannot gain positive profit in case BC. Hence, the firm does not consider case BC. Unlike strong property rights, the dominant firm does not use both technologies in the second period. Now we find out the condition under which the firm adopts inferior technology B as de facto standardization. This case holds if the following inequalities are satisfied.

$$\Pi_{BB} - \Pi_{AA} = (2\Delta V + 2N)N - K_B > 0.$$

Therefore, it is necessary that $0 > \Delta V > -N$.

Suppose that technology B which can make a degraded product is available in the second period. Under weak property rights, the dominant firm adopts inferior technology B as de facto standardization if and only if $(2\Delta V + 2N)N > N > K_B > 0$. Proposition 3 summarizes the discussion of weak property rights case.

Proposition 3 : As under strong property right, the dominant firm will have an incentive to practice planned obsolescence. However, weak property rights may accelerate planned obsolescence more than strong property rights will. Furthermore, the firm may adopt inferior technology B as the de facto standard. That means that contrary to the situation under strong property rights, the firm does not use compatible technologies under weak property rights.

There are some remarks of Proposition 3. First, the time-inconsistent problem does not arise when the dominant firm faces competition when it sells product A in the second period under weak property rights. This is because we can easily show that when the dominant firm has the ability to commit to its second period technology in the first period, its actual technology choice in the second period is identical with the choice it would make if it could commit its second-period technology in the first period. Second, the dominant firm under weak property rights has less profit when it continues to provide product A in the second period than it would under strong property rights. Thus, under weak property rights it has more incentive to introduce new technology than under strong property rights. As with no price discrimination in Choi (1993), under weak property rights social inefficiency may arise. Finally, this analysis analogously applies to the case where the dominant firm has property rights for technology A in the first period, and the competitor has property rights for B in the second period. Therefore, we conclude that, as in Katz and Shapiro (1986), the tendency to standardization on the emerging technology B may arise in inter-temporal competition between technologies with well-defined property rights. Furthermore, although inter-temporal competition is assumed, inferior technology B still may be adopted as de facto standardization in the second period.

3. Openness of Forward Compatibility

We consider the third way that compatibility technology between old

and new products is opened to everybody. This means that the dominant firm should open the information necessary for competitors' compatibility with its new product B. Therefore, a competitive firm can provide not only product A but also forward compatibility in the second period. Competitive firms have the same forward compatibility costs c_f that the dominant firm does. Now we can derive the profits in the following three cases. We first investigate case AA. Similarly to the case of weak property rights, it is easily seen that the profit in the second period from this case is given by $\Pi_{AA}=0$.

Second, in case BB, competitive firms have access to forward compatibility technology. It is easily shown that they provide upgrade product A_U with cost c_f in the equilibrium. Thus, we can write incentive constraints of both groups as follows.

$$(V_B+2N)-p_{iB}^2 \geq (V_A+2N)-c_f.$$

Therefore, the profit in the second period from this case is given by

$$\Pi_{BB}=(\Delta V+c_f)2N-K_B.$$

Finally, we consider the cases in which the firm chooses to provide technologies A and B in the second period. Similar to the case of weak property rights, the dominant firm cannot increase its profit by providing forward compatibility. Therefore, the maximal profit in the second period from these cases is given by

$$\Pi_{BC}=(\Delta V-c_b)N-K_B.$$

However, it is easily seen that, as with weak property rights, this case is dominated by two other cases for all values of ΔV. Therefore, in order to derive the firm's optimal policy, it is sufficient to compare Π_{BB} with Π_{AA}. In this case, since $\Pi_{BB}-\Pi_{AA}=\Pi_{BB}\geq 0$, technology B is adopted if and only if $\Pi_{BB}=(2\Delta V+c_f)N-K_B\geq 0$. Therefore, planned obsolescence may happen. However, the smaller the forward compatibility cost c_f is, the

smaller the the range of distortion is. Proposition 4 summarizes the conclusions under weak property rights.

Proposition 4 : In the absence of forward compatibility cost, the openness of forward compatibility makes private firm's incentive aligned with that of the social planner in the second period. Thus, it prevents the dominant firm (or competitor) not only from implementing planned obsolescence in the second period but also from providing degraded goods.

In comparison with weak property rights, the reason why this holds is as follows : Weak property rights may induce the monopolist not to introduce technology A. In order to extract a higher surplus from group 1, the dominant firm will try to devalue the old product that group 1 has possessed. When product A is forward-compatible with B, group 1 consumers are willing to pay only the differences in stand-alone benefits (ΔV) for the new product, since they can enjoy the same number of network externalities. On the other hand, if product A is not forward-compatible with B, group 1 consumers are willing to pay the difference in stand-alone benefits (ΔV) for the new product, plus the differences in the network externalities (N). The fear of being left behind by group 2 forces group 1 consumers to pay more for B than they would pay in the case of openness of forward compatibility. Therefore, in this case the dominant firm has less profit when it introduces product B as a de facto standard in the second period than under weak property rights. This relative disincentive for introducing new technology makes a private firm's incentive to introduce a new product aligned with that of the social planner in the second period.

Ⅴ. Concluding Remarks

Now we summarize the conclusions of this model and discuss the directions in which to extend the analysis. We have examined how varying

the property rights affects the adoption of technologies and the compatibility between products with demand side and supply side economies of scale. In this environment, we obtain the following main results : First, social welfare is maximized by having all consumers use the same technology in the second period. Second, contrary to this, the dominant firm's incentive to introduce a new product that makes the old unit obsolete is too high ; that is, it will have an incentive to practice planned obsolescence. In particular, even though a new product is inferior to an old product, if the dominant firm can access degradation technology and compatible technology with relatively low cost, strong property rights induce the dominant firm to use both technology and compatible technologies. Finally, under weak property rights, we show that in the absence of forward compatibility cost, the openness of forward compatibility makes a private firm's incentive aligned with that of the social planner in the second period. Thus, it prevents the dominant firm (or competitor) from doing planned obsolescence in the second period. Furthermore, as mentioned, this case applies to the case wherein the competitor has the property rights to technology B. Therefore, openness of forward compatibility prevents the competitor from doing planned obsolescence. However, since the conclusions are affected by the costs of forward compatibility, they do not always justify the policy enforcement of forward compatibility.

The model here is only beginning. We should investigate how the results are affected by the various enrichments of the model as follows. First, as mentioned earlier, the KFTC imposed a remedy ordering Microsoft to sell a unbundled version of its Windows Operating System without Windows Media Player and Windows Messenger. Some opponents of the remedy claimed that the KFTC remedies that strip out functionality can ultimately harm innovation and the consumers who benefit from it. In addition, the KFTC decided that Microsoft makes the necessary information available for competitors' compatibility with the Microsoft operating system. However, the second remedy is not a sufficient condition to prevent the dominant firm from doing planned obsolescence. This can be

justified when competitors can provide a perfect substitute for product A and forward compatibility can be provided at sufficiently low cost in the second period. Thus, under weak property rights, the remedy prevents the dominant firm from doing planned obsolescence in the second period. However, it is obvious that the dominant firm's profit under weak property rights is lower than that under strong property rights for all cases. As with unbundled version selling, weak protection for property rights may inhibit innovation. In our model, this may induce the firm not to introduce technology A in the first period. Thus, in the presence of fixed costs socially valuable innovations will not occur under weak property rights. However, it would be efficient ex post to make existing ideas freely available to all producers. Moreover, the openness of forward compatibility prevents a firm from doing planned obsolescence. As mentioned in Barro and Sala-i-Martin (1999), a trade-off arises between restrictions on the use of existing ideas and the rewards to inventive activities. Considering this trade-off, we further investigate the institution of optimal property rights in the general model. Second, we adopt the two-period model where the end of world effect exists. However, this effect may weaken in the multi-period model where the firm is concerned about how its current behavior affects the value of the new product scheduled to be introduced. Therefore, we need to investigate whether the results of this paper are robust in the multi-period model. Finally, our results heavily depend on the assumption that consumers of the same group coordinate on reluctant equilibrium and perfect foresight in the value of future technology. Thus, explicitly dynamic models reflecting various behavior rules and imperfect information are needed to study the robustness of our conclusions.

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APPENDIX

Proof of Lemma 1

Let x_i denote the share of group i consumers who use product A in the second period. We easily know that the maximum profit in the market B is decreasing in x_2. Thus, in order to maximize the profit, the firm does not sell product A to group 2 in the second period, i.e., $x_2=0$. We can write the relevant incentive constraints of both groups as follows :

$$V_B+N+\chi_B(x)N+(1-\chi_B(x))(1-x_1)N-p_{1B}^2 \geq V_A+x_1N, \qquad \text{(A1)}$$

$$V_B+N+\chi_B(x)N+(1-\chi_B(x))(1-x_1)N-p_{2B}^2 \geq 0. \qquad \text{(A2)}$$

where χ_B is the characterize function, and B represents backward compatibility. Thus, the function has "1" if the firm provides backward compatibility or de facto standardization of technology B, which means $x_1=0$. Otherwise, the characterize function has "0".

The first incentive constraint is for group 1 consumers, since they can continue to use product A in the second period. And the second incentive constraint is for group 2 consumers. Inequality (A1) assumes that the firm does not provide forward compatibility. Now, we investigate whether the firm provides the forward compatibility for group 1 or not. Since providing forward compatibility for group 1 increases the value of continuing to use product A, that is, the right hand side of inequality (A1) increases from V_A+x_1N to V_A+2N. In order to extract higher surplus from group 1, the firm will try to devalue product A. Therefore, the firm does not provide forward compatibility in this case. Now, we check whether the firm provides backward compatibility or not.

At first, we find out the maximum price charged to a group 2 consumer. The inequality (A2) is related to the price charged to a group 2 consumer. Since providing backward compatibility increases the value of purchasing product B, that is, the left-hand side of the inequality increases from $V_B+N+(1-x_1)N$ to V_B+2N. Without backward compatibility,

the value of purchasing product B depends on x_1 and has a maximum at $x_1 = 0$. Therefore, the maximum price charged to a group 2 consumer is $p^2_{2B} = V_B + 2N$.

Next, we find out the maximum price charged to a group 1 consumer. We compare the firm's maximum price for group 1 p^2_{1B}, providing backward compatibility with providing non-backward compatibility. In the case of backward compatibility, we find the firm's maximum price for p^2_{1B}. Note that with backward compatibility, the left-hand side of inequality (A2) does not depend on x_1. Therefore, in the subgame price p^2_{1B}, there are the following equilibriums : If $p^2_{1B} \leq V_B - V_A + N = p^*_{1B}$ corresponding to $x_1 = 1$, the unique equilibrium is to purchase product B. For $p^2_{1B} \geq V_B - V_A + 2N = p^*_{1B}$ corresponding to $x_1 = 0$, the unique equilibrium is that all group 1 consumers remain with product A. In the subgame following the price $p^*_{1B} < p^2_{1B} < p^{**}_{1B}$, there are two pure strategy equilibrium-"all purchase product B" and "all stick with product A"-as well as an equilibrium mixed strategy. We will choose the uniform selection rule, the reluctant rule that means "purchase when $p^2_{1B} < p^*_{1B}$." If group 1 coordinates on the so-called "the reluctant rule," the dominant firm sets the price. In this case, group 1 customers' payoff in the subgame is higher than with any other coordination rule. From (A1), we have $p^2_{1B} \leq V_B - V_A + N$. Therefore, $p^{*BC}_{1B} = V_B - V_A + N$. Now, in the case of non-backward compatibility, we find the firm's maximum price for p^2_{1B}. Assuming non-backward compatibility, from (A2) we have

$$V_B + N + (1 - x_1)N - p^1_{2B} \geq V_A + x_1 N.$$

Since we choose the reluctant rule, if $p^2_{1B} \leq V_B - V_A = p^{*NB}_{1B}$ (which is corresponding to $x_1 = 1$), the unique equilibrium is to purchase product B. This means all group 1 consumers purchase product B when $p^2_{1B} \leq p^{*NB}_{1B}$. Thus, the difference of the firm's maximum price between providing backward compatibility and providing non-backward compatibility is $p^{*BC}_{1B} -$

$p_{1B}^{*NB} = N$. Therefore, it can increase profit from not only group 1 but also group 2 by providing backward compatibility. Furthermore, if the firm sets the prices $p_{1B}^{2} = V_B - V_A + N$ and $p_{2B}^{2} = V_B + 2N$, all consumers purchase product B. Thus, it makes technology B de facto standardization by having all consumers purchase product B. it does not incur cost for backward compatibility. Hence, the profit in the second period from this case is given by

$$\Pi_{BB} = (\Delta V + N)N + (V_B + 2N)N - K_B. \quad \blacksquare$$

Proof of Lemma 2

We consider the cases in which technologies A and B are employed in the second period, i.e., case TC and case BC. In the case TC, here the dominant firm sets the price for the consumers, offering an upgrade product A_u low enough that all group 1 consumers purchase a unit A_u in the second period. Note that the second period payoff to upgrade is $V_A + 2N - p_u$, irrespective of the play of other consumers, while the second period payoff to continue use of product A is $V_A + x_1 N + x_2 N$. Similarly to in the case BB, in order to maximize profit, the firm does not sell product A to group 2 in the second period, i.e., $x_2 = 0$.

We can write the relevant incentive constraints of both groups as follows.

$$V_A + 2N - p_u \geq V_A + x_1 N, \tag{A3}$$

$$V_A + 2N - p_u \geq V_B + 2N - p_{2B}^{2}, \tag{A4}$$

$$V_B + N + \chi_B(x)N + (1 - \chi_B(x))(1 - x_1)N - p_{2B}^{2} \geq 0. \tag{A5}$$

The first two constraints are related to group 1 consumers, and the third one is related to group 2 consumers. First, we find the firm's maximum price for p_{2B}^{2}. We observe that if inequality (A5) is not binding, the firm can increase p_{2B}^{2}. Therefore, we know that the binding constraint for p_{2B}^{2} at optimum is (A5). However, we easily know that compared with non-backward compatibility, backward compatibility increases the value of

the left-hand side of inequality (A5). Hence, the firm provides backward compatibility and sets the price $p_{2B}^{2} = V_B + 2N$. Now, we find out the firm's maximum price for p_u. We observe that the relevant constraint is (A3). Assuming the reluctant rule, if $p_u \leq N = p_u^*$ corresponding to $x_1 = 1$, the unique equilibrium is to upgrade. Since $N > c_f$, the firm increases its profit $(N > c_f)N$ supplying upgrade product at price $p_u = N$. From the above results, we know that case BC is dominated by case TC. Hence, under strong property rights, when the dominant firm chooses to provide technologies A and B in the second period, the firm can increase profit by providing not only backward compatibility but also forward compatibility.

Thus, the profit in the second period from this case is given by

$$\Pi_{TC} = (N - f)N + (V_B + 2N - b)N - K_B. \quad \blacksquare$$

〔Abstract〕

지적 재산권과 계획적 진부화

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본 연구에서는 수요측면뿐만 아니라 공급측면에서 규모의 경제가 존재할 때, 지적 재산권 보호의 정도가 기술의 선택과 호환성에 어떠한 영향을 주는지를 고찰한다. 이러한 환경에서 본 연구는 다음의 결론을 얻고 있다: 첫째, 사회후생은 모든 소비자들이 대체기술이 이용 가능한 다음 기에 동일한 기술을 이용할 때 최대화된다. 둘째, 강한 지적재산권 보호는 지배적인 기업이 사회적으로 비효율적인 호환 기술을 도입하게 한다. 셋째, 약한 지적재산권의 보호는 계획적 진부화를 가속화할 수 있다. 마지막으로 약한 지적재산권 보호를 할 때 전방 호환성의 개방은 독점기업이 계획적 진부화를 하는 것을 방지할 수 있다.

핵심용어 : 재산권, 전방 호환성, 계획적 진부화