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Simple Economics of Backward Compatibility in the Presence of Network Effects

by

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Simple Economics of Backward Compatibility in the Presence of Network Effects*

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Abstract

We analyze the effects of an incumbent's investment in backward compatibility of new products with old ones in the presence of network effects. Under consumers' utility function consisting of two components, "stand-alone valuation" and "network-dependent valuation", we show that incumbent's investment level in backward compatibility always exceeds the social optimum because it raises consumers' switching costs in socially undesirable way. In addition to this, this divergence of incumbent's investment from a socially optimal one strongly depends on consumers' utility. Using a specified utility function, it is shown that this divergence could increase with the degree of complementarity between two components in utility function under some situations.

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1. Introduction

Recently, in many industries such as the computer industry and the household electrical appliances industry, formation and preservation of *de facto* standards have very important roles for business strategies. In these industries, products are often required to be supplied together with their compatible software, so that there can be strong network effects because of consumers' "mix and match" behavior (Matutes & Regibeau (1988)) and/or increasing return to scale of software production (Chou & Shy (1990)). Since Katz & Shapiro (1985) and Farrell & Saloner (1985), many authors have researched the implications of network effects on the competition for *formation* of *de facto* standards. Through their contributions, we have understood that a firm's supplying of a product that is compatible with a rival's products could constitute an important business strategy for *formation* of *de facto* standards.

By contrast, firms that have already acquired *de facto* standards face the problem of how they can *preserve* their position. When a firm that has a large installed base decides to introduce new product, it has to determine the degree of compatibility of its new product with its old ones—backward compatibility.[1] However, in this decision, the firm faces the following trade-off: it could hurt its installed base by introducing a relatively incompatible product, while to maintain compatibility with old products, in general, it has to invest resources.

Several authors have researched determination of backward compatibility in the presence of network effects. For example, Katz & Shapiro (1992) studied the date of introduction of new products in rigorous dynamic settings and showed that firms that have an installed base tend to introduce relatively incompatible new products. Whereas, Choi (1994) analyzed determination of backward compatibility levels in the case of a durable goods monopolist approach. He proved that a monopolist can attain profitable planned obsolescence through introducing incompatible new products. In this meaning, these two studies showed that incumbents would be inclined to choose a low degree of backward compatibility.

It can be observed, however, that backward compatibility levels are different among various products. For example, in the Japanese video-game market, Nintendo,

[1] "Backward compatibility is defined as the ability of the new product to subscribe to the benefit of old product's network"(Choi (1994), p.173). Of course, there is also the concept of forward compatibility. For simplicity, we ignore this possibility.

which already has a large installed base through the success of "Family Computer," introduced new but almost perfectly incompatible machines, "Super Famicom" and "Nintendo 64." By contrast, in the Japanese personal computer market, it is well known that NEC, which also has a large installed base through the introduction of its "PC-98 series," has given relatively large backward compatibility to its new personal computer models. What factors account for this difference?

In this paper, to explain this phenomenon and to examine its implications, we note the form of consumers' utility function. In fact, Katz & Shapiro and Choi assumed that the consumers' utility function would be represented by the sum of two components; "stand-alone valuation" and "network-dependent valuation." This assumption may be inadequate in considering the two markets cited in the previous paragraph, for consumers of the above two products may have extremely different preferences. Recently, Shy (1996) noted the relation between the two components in the consumers' utility function, and showed that this relation affects the duration of each product strongly. Although this research provides useful insight into the effects of backward compatibility, the author treated the compatibility level as exogenous. In order to focus upon the determination of backward compatibility levels, we consider the behavior of an incumbent who has an installed base and faces potential entrants. Through this consideration, we examine the implication of the incumbent's decision in favor of backward compatibility and the relation between the two components in the consumers' utility function.

The main results of our analysis are as follows: (1) Under consumers' utility function consisting of two components, "stand-alone valuation" and "network-dependent valuation," incumbent's investment level in backward compatibility always exceeds the social optimum. (2) Divergence of incumbent's investment from the socially optimal one strongly depends on consumers' utility. (3) This divergence could increase with the degree of complementarity between the two components in utility function under some situations.

This paper is organized as follows. Section 2 explains the framework of our model. Using this framework, the effects and the welfare implications of an incumbent's decision with regard to investment in backward compatibility is illustrated in Section 3. Section 4 examines how the complementarity between the two components in the consumers' utility function effects incumbent's decision. Section 5 concludes with a brief discussion of antitrust implications and further extensions.

2. The Model

To treat the above problems, consider the following model. There are N consumers, who have already purchased perfect durable goods with network effects and are considering buying improved versions. There are no new buyers arriving at the market. So, we consider only the repeat purchasing behavior of N consumers. The utility of each consumer is identical that of to each of the others and depends on the following two factors. The first, "stand-alone valuation" is the intrinsic value of the product to the consumer. Let v_0 be the consumers' "stand-alone valuation" of the old product, and v_i be this valuation of the improved version of the product supplied by firm i. The second factor is "network-dependent valuation" which shows the network effects of the product. In this model, it is assumed that consumers' demand is perfectly inelastic, and each consumer purchases at most one unit of the goods. Under this assumption, as network effects mean that the utility of the product is increased by the number of users of this product, we can write "network-dependent valuation" as this number N. So, the consumers' utility function can be represented by the function $U(v_j, N)$; j=0 or i. We assume that this function has the following natural property: $U_1 > 0$, $U_2 > 0$, $U_{11} \leq 0$, $U_{22} \leq 0$, where subscripts denote derivatives of the function by corresponding arguments.

An incumbent (firm 1), which has already sold the old version of the goods to the consumers and has an installed base, develops a new superior version of the product without development costs.[2] Facing a potential entrant (firm 2), it considers the backward compatibility level of the new product with its older ones. By investing x, it can attain the backward compatibility level $c(x)$. We assume that the function $c(x)$ has the "well-behaved" property:[3] $c(0) = 0$, $c(\infty) = 1$, $c'(x) > 0$, $c''(x) < 0$ and $c'(0)$ is sufficiently large.[4] The backward compatibility makes the new product attractive for the consumers because of network effects. Assuming that consumers can coordinate

[2] As long as development costs are constant, the following conclusions are substantially unchanged.

[3] This property means that backward compatibility is imperfect. As pointed out in Chou & Shy (1993), many products, e.g., computer software, have only partial (backward) compatibility due to addition of functions to the new product.

[4] More rigorously, it is sufficient that $c'(0) > 1 / N(U_2 N + s'(0))$ holds.

their purchasing decisions, consumer's (effective) "network-dependent valuation" of this new product becomes $(1+c(x))N$.[5] On the other hand, the potential entrant can also develop its new product with no development costs. Given the incumbent's behavior, the entrant can produce only a product that is perfectly incompatible with firm 1 products, because of, perhaps, the incumbent's patent. For simplicity, we assume that the marginal and average costs $\bar{c}$ of the new products are constant and the same for both incumbent and entrant. Moreover, it is assumed that Bertrand competition will occur in the new product market.

In the market of the new product, consumers make purchasing decisions simultaneously. Under this environment, there could be multiple Nash equilibria for some prices. To avoid complex refinement problems, we assume consumers choose the Pareto-optimal outcomes.[6] So, when consumers purchase the new product from the incumbent their utility is described by $U(v_1,(1+c(x))N)$, while the utility becomes $U(v_0,N)$ if the consumers decide to stay with the old product of the incumbent. On the other hand, when they purchase the new product from the entrant, they enjoy utility $U(v_2,N)$. However, the incumbent's investment in backward compatibility not only affects "network-dependent valuation" of their own product, but also the attractiveness of their rival's product through the consumers' switching costs. That is, if consumers switch from the old product of the incumbent to the new product of the entrant, they are forced to bear the switching cost, s.[7] Due to accumulated "product-specific" assets by consumers, when incumbent's new product has greater backward compatibility, consumers hesitate to switch to the incompatible product. Therefore, we assume that switching costs are described by a function that has the following property: $s(0)=0$, $s'(c(x))>0$, $s''(c(x))<0$. Furthermore, it is assumed that this function has an upper bound $\tilde{s}=s(1)=U(v_2,N)-U(v_0,N)-\bar{c}$. That is, switching costs cannot be so large as the increase in utility which the entrant can give to the consumers. This assumption enables us to exclude uninterested outcomes in which

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[5] In our setting, network effect is represented by the amount of installed base. By introducing new product, installed base is increased by the amount of $c(x)N$.

[6] If consumers make their purchasing decisions in a pre-determined order, the only subgame perfect equilibrium would be Pareto-optimal in the setting of complete information. See Farrell & Saloner (1985).

[7] For rigorous treatment of switching costs, for example, see Klemperer (1987) and Farrell & Shapiro (1988).

consumers continue to use the old product. In addition to this, because we are interested in the incumbent's entry-deterrence behavior, we concentrate on the situation where the incumbent wins the competition in the new product market.

3. Incumbent's Behavior and its Welfare Implications

Under this framework, we first consider the consumers' decision. Consumers purchase the new product from the incumbent if both the following conditions are satisfied:

$$U(v_1,(1+c(x))N)-p_1 \geq U(v_2,N)-p_2-s(c(x)), \tag{1}$$

$$U(v_1,(1+c(x))N)-p_1 \geq U(v_0,N), \tag{2}$$

where p_i denotes the price of firm i's new product. Condition (1) states that consumers enjoy larger utility if they purchase the product from the incumbent rather than from the entrant. Inequality (2) shows that utility from purchasing incumbent's new product exceeds reservation utility.

The incumbent sets the price of its new product taking these conditions into account. Because Bertrand (price) competition prevails in the market, the maximum price of firm 1's new product, which deters entry, is as follows:

$$p_1 = U(v_1,(1+c(x))N)-U(v_2,N)+s(c(x))+\bar{c}. \tag{3}$$

Then, profit of incumbent, π_1 is represented by

$$\pi_1 = [U(v_1,(1+c(x))N)-U(v_2,N)+s(c(x))]N-x. \tag{4}$$

As we concentrate on the situation in which the incumbent wins the new product market, we assume that there are some x which will make equation (4) positive. In this situation, considering that the price of the entrant's new product is given by $\bar{c}$, and that consumers' switching cost has the upper bound $\tilde{s}$, we can show that (1) implies (2). Therefore, the problem of firm 1 is merely maximizing its profit (4). This maximization leads firm 1 to choose the degree of backward compatibility of its product necessary to deter entry and to force consumers to purchase the new product.

First-order condition of this maximization problem is described by

$$[U_2Nc'(x)+s'(c(x))c'(x)]N=1. \tag{5}$$

Under our framework, this maximization causes interior solution, x^*. Added to this, second-order condition of this problem, $d^2\pi_1/dx^2<0$, is also satisfied in our framework.[8] Incumbent chooses its investment level—so, the degree of backward compatibility which will equate its marginal revenue to its marginal cost. Notice that its marginal revenue consists of two factors. The first, by increasing investment in backward compatibility, incumbent confers greater utility on the consumers through network effects. At the same time, increasing incumbent's investment also raises switching costs to consumers. This prevents the consumers' switching behavior to rival's product, and raises incumbent's profit.

In order to examine the importance of the relation between "stand-alone valuation" and "network-dependent valuation" within the utility function, it is useful to perform comparative statics analysis. Differentiating first-order condition (5) totally, the effect of the change of "stand-alone valuation" on optimal investment to backward compatibility is represented by the following equation:

$$\frac{dx^*}{dv_1} = -\frac{U_{21}N^2 c'(x)}{d^2\pi_1 / dx^2}. \qquad (6)$$

(6) shows that the effect of the change of "stand-alone valuation" strongly depends upon the relation between two components in the utility function. In fact, we have the following proposition.

Proposition 1: Under the complementary (substitutional) relation between "stand-alone valuation" and "network-dependent valuation" in utility function—that is, $U_{21} > (<) 0$*, increases in* v_1 *raise (reduce) incumbent's optimal investment in backward compatibility—thus, the degree of backward compatibility.*

Remark: Notice that incumbent's optimal investment level is not influenced by increases in "stand-alone valuation," when the two components in the utility function are separable from each other—for example, if consumers' utility function has the form, $U = v_1 + u(1 + c(x)N)$. For, in this case, the change of "stand-alone valuation" does not affect marginal utility of "network-dependent valuation."

We can interpret consumers' "stand-alone valuation" as the quality of incumbent's new product. If the two components in the utility function have a complementary

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[8] Second order condition is $\left[U_{22}(NC')^2 + U_2 Nc'' + s''(c')^2 + s'c''\right]N < 0$ in abbreviated form.

(substitutional) relation, consumers place more (less) value on network effects of this new product when innovation embodied in the product becomes drastic. As a result, incumbent can enjoy more profit by increasing (decreasing) the degree of backward compatibility. In this meaning, the above proposition suggests to us the importance of the form of the utility function in examining the backward compatibility level.

Now, let us turn to the problem of welfare maximization. Consider a social planner who knows that consumers will choose a Pareto-optimal outcome. This planner could choose the backward compatibility level of incumbent's new product through determination of *de juri* standards. In our model, consumers have three options: to purchase a new product from the incumbent, to purchase from the entrant or to stay with the old product of the incumbent. In this situation, considering that consumers have perfectly inelastic demand, to maximize social welfare, the social planner merely examines the following equation:

$$\Delta W = \max.\Big[\max_x.\{[U(v_1,(1+c(x))N) - U(v_0,N) - \bar{c}]N - x\},$$

$$\max_x.\{[U(v_2,N) - U(v_0,N) - s(c(x)) - \bar{c}]N - x\}, 0\Big], \tag{7}$$

where ΔW denotes the increase in social welfare. Needless to say, each argument in the right-hand side of (7) shows a maximum increase in the welfare society enjoys when consumers choose the above three options; to purchase a new product from the incumbent, from the entrant or to stay with old product, respectively.

Considering that incumbent's profit (4) is assumed to be non-negative, and that consumers' switching costs have upper bound $\bar{s}$, we can show that the first argument in the right-hand side of (7) is greater than the third argument. On the other hand, the second argument is decreasing with x. So, this argument attains the maximum value at $x = 0$. That is, we can transform (7) as follows:

$$\Delta W = \max.\Big[\max_x.\{[U(v_1,(1+c(x))N) - U(v_0,N) - \bar{c}]N - x\},$$

$$[U(v_2,N) - U(v_0,N) - \bar{c}]N\Big]. \tag{8}$$

When the second argument in the right-hand side of (8) is greater than the first argument, that is, when there is no x satisfied $U(v_1,(1+c(x))N)N - x \geq U(v_2,N)N$, the socially optimal investment level is 0. In this case, the market solution obviously exceeds the socially optimal amount. Conversely, when there are some x satisfied $U(v_1,(1+c(x))N)N - x \geq U(v_2,N)N$, it is socially optimal that the amount of the first argument in the right-hand side of (8) be maximized. Differentiating this argument with x, we can obtain the first-order condition of welfare maximization in this case.[9] That is,

$$U_2 N^2 c'(x) = 1 . \tag{9}$$

Let us evaluate the first-order condition of incumbent's profit maximization problem at the socially optimal investment level x^s which satisfies (9). Then, from (5) and (9), it holds that

$$\left.\frac{d\pi_1}{dx}\right|_{x^s} = U_2 N^2 c'(x^s) + s'(c(x^s))c'(x^s)N - 1 > \left.\frac{d\Delta W}{dx}\right|_{x^s} = 0 . \tag{10}$$

From the above discussion, we can derive the following proposition.

Proposition 2: Incumbent's investment level to backward compatibility exceeds the socially optimal amount, that is $x^* > x^s$ *. Therefore, the market tends to cause socially excessive backward compatibility.*

Notice that we can rewrite the condition of a positive incumbent's profit as $U(v_1,(1+(c(x))N)N - x > \left[U(v_2,N) - s(c(x))\right]N$. Therefore, there exists some situations which satisfy $U(v_2,N)N > U(v_1,(1+c(x)N)N - x, \forall x$, and make incumbent's profit positive. This consideration leads us to the next proposition.

Proposition 3: There are some situations in which consumers choose the incumbent's new product due to the incumbent's investment in backward compatibility, though it is socially optimal that consumers switch to rival's new product.

Economic interpretation of these propositions is very simple. As mentioned above, incumbent can raise its profit by increasing its investment level in backward compatibility through two routes. (1) By network effect based on the previously sold old product, incumbent provides greater utility to the consumers. (2) By raising switching costs of the consumers, incumbent can "lock-in" consumers to its own products and prevent consumers' switching to the rival's product. Socially, effect (2) is undesirable. So, incumbent invests excessively in backward compatibility. More importantly, the benefit the potential entrant can provide is reduced by these

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[9] Second order condition is also satisfied, that is, $U_{22}N^3(c'(x))^2 + U_2 N c''(x) < 0$.

switching costs. By increasing the degree of backward compatibility, the incumbent can raise its rival's cost indirectly. This increase in the rival's cost makes the incumbent's entry-deterrence behavior easy and effective. However, this entry-deterrence behavior is never socially desirable.

4. Substitutability vs. Complementarity between Two Components in Utility Function: An Example

When we consider backward compatibility of new goods, our discussion in the previous section suggests the importance of substitutability (complementarity) between two components in utility function: "stand-alone valuation" and "network-dependent valuation." To make the argument clearly, in this section we specify utility function as a quadratic form.[10] This quadratic form of utility function can be represented by

$$U(v_j, n) = \alpha_1 v_j + \alpha_2 n - \frac{1}{2}\left(\beta_1 v_j^2 + 2\gamma v_j n + \beta_2 n^2\right), j = 0,1,2; n = N, (1 + c(x))N \text{, (11)}$$

where $\alpha_1, \alpha_2, \beta_1, \beta_2 > 0, \beta_1\beta_2 > \gamma^2$. Under this specification, substitutability between two components is described by the sign of γ. That is, positive (negative) sign of γ means that the two components are substitute (complement).

Using this utility function, we can write incumbent's profit (4) as follows:

$$\pi_1 = \left\{\alpha_1 v_1 + \alpha_2(1 + c(x))N - \frac{1}{2}\left(\beta_1 v_1^2 + 2\gamma v_1(1 + c(x))N + \beta_2\left[(1 + c(x))N\right]^2\right)\right\}N$$
$$- \left\{\alpha_1 v_2 + \alpha_2 N - \frac{1}{2}\left(\beta_1 v_2^2 + 2\gamma v_2 N + \beta_2 N^2\right) - s(c(x))\right\}N - x. \quad (12)$$

In the same way as the previous section, let us concentrate on the situation in which (12) is non-negative. Then, it follows that the first-order condition of incumbent's profit maximization yields

$$\left\{N\left[\alpha_2 - \gamma v_1 - \beta_2(1 + c(x))N\right] + s'(c(x))\right\}c'(x)N = 1. \quad (13)$$

Moreover, second-order condition, which is satisfied under our assumptions, can be written by

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[10] This utility function is often used in economics of information. See, for example, Sakai (1990).

$$\frac{d^2\pi_1}{dx^2} = c''(x)N\{N(\alpha_2 - \gamma v_1 - \beta_2(1+c(x))N) + s'(c(x))\}$$

$$- c'(x)N\{N^2\beta_2 c'(x) - s''(c(x))c'(x)\} < 0 . \quad (14)$$

By using a procedure similar to that in the previous section, we can perform comparative statics analysis. Especially, the effect of γ on x^* is interesting for our purpose. Then,

$$\frac{dx^*}{d\gamma} = \frac{v_1 c'(x)N^2}{d^2\pi_1 / dx^2} < 0 . \quad (15)$$

Therefore, we can obtain proposition 4, which is a variant of proposition 1, under our specification of utility function.

Proposition 4: Increase in complementarity between "stand-alone valuation" and "network-dependent valuation" leads the incumbent to raise investment level in backward compatibility of the new product.

To compare incumbent's optimal investment with the social optimum, we are required to describe the social welfare function. Under our specification, we can write (8) as follows:

$$\Delta W = \max.\left[\max_x . F(x), G\right], \quad (16)$$

where

$$F(x) = \{\alpha_1(v_1 - v_0) + \alpha_2 c(x)N\}N$$

$$-\frac{1}{2}\left[\beta_1(v_1^2 - v_0^2) + 2\gamma v_1 c(x)N + 2\gamma N(v_1 - v_0) + \beta_2\left\{[(1+c(x))N]^2 - N^2\right\} - \bar{c}\right]N - x$$

$$G = \left\{\alpha_1(v_2 - v_0) - \frac{1}{2}\left[\beta_1(v_2^2 - v_0^2) + 2\gamma N(v_2 - v_0)\right] - \bar{c}\right\}N .$$

The conditions[11] by which social welfare is maximized can be written by

[11] When the first argument in the right-hand side of (17) is greater than the second argument, we are required to check the second-order condition of social welfare maximization. Under our framework, this condition is also satisfied; that is,

$$\frac{d^2\Delta W}{dx^2} = c''(x)N^2\left[\alpha_2 - \gamma v_1 - \beta_2(1+c(x))N\right] - \beta_2 c'(x)^2 N^3 < 0 .$$

x^s satisfies $c'(x)N^2[\alpha_2 - \gamma v_1 - \beta_2(1+c(x))N] = 1$,

if $\max_x . F(x) \geq G$

$x^s = 0$, otherwise. (17)

Comparing (13) with (17), we can easily check the validity of proposition 2 and 3.

Recall that under the situation in which proposition 3 holds, society can maximize social welfare by introducing a new rival product that is perfectly incompatible. On the other hand, we know that the incumbent's optimal investment is increasing with the degree of complementarity from (15). So, we can derive the following proposition.[12]

Proposition 5: Consider the situation in which proposition 3 holds. In this case, increase in the degree of complementarity between "stand-alone valuation" and "network-dependent valuation" enlarges divergence of market solution from social optimum.

Economic interpretation of this proposition is also simple. Increase in the degree of complementarity between "stand-alone valuation" and "network-dependent valuation" means that the two components are positively related. Under this situation, the incumbent invests more and more in compatibility, because by doing so it can enjoy a larger profit through raising the price of the new product. Whereas, this raises the consumers' switching cost and easily enables the incumbent to deter entry. However, this latter effect is socially undesirable. Therefore, an increase in the degree of complementarity between two components in utility function enlarges the disparity between market solution and social optimum.

This proposition suggested to us the importance of the degree of complementarity between two components in utility function. Shy (1996) interpreted this complementarity (substitutability) as the rigidity (flexibility) of consumers' use of the product from being centralized to decentralized while maintaining the same "stand-alone valuation."[13] Let us apply this interpretation to the "systems market" and consider the implications of the proposition.

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[12] Even if we consider the situation in which proposition 3 does not hold, under tedious condition there exists the environment in which the next proposition holds.

[13] See Shy (1996), p.787.

In the "systems market," hardware must often match with compatible software. Under this hardware/software paradigm, it is well known that the preference on hardware has a large network effect because of, e.g., the availability of its software and/or increasing returns to scale of the production of software. On this setting, the above rigidity (flexibility) could strongly depend on the continuity of the value of software over time. Consider, for example, video-game products. In general, video-game software has only short continuity of value, because users of video-game software experience a large reduction of economic value when they finish the video-game. This tendency permits consumers to have flexibility of their use from any specific game to other games. Consumers' preference on the video-game machine also has this flexibility. Therefore, on this kind of product, relation between "stand-alone valuation" and "network-dependent valuation" is relatively substitute. In this case, the degree of backward compatibility is relatively small. In addition to this, under the situation in which proposition 5 holds, disparity between market solution and social optimum tends to be small.

On the contrary, consumers' preference for hardware whose software has long continuity of value tends to "rigidity." Consider, for example, personal computers. Users of a personal computer have many useful files which were made on a specific hardware/software combination. These files are often useful for doing their work, so continue to keep their economic value. Under this environment, users of a personal computer hesitate to change their use of a computer from this specific computer to other ones. Therefore, their preference for a personal computer is "rigidity," so the relation between "stand-alone valuation" and "network-dependent valuation" becomes relatively complementary. There is a relatively high degree of backward compatibility around this type of product. Moreover, disparity between market solution and social optimum may be serious.

5. Concluding Remarks

We have discussed the implications of incumbent's investment in backward compatibility using a very simple model. Our analyses have shown that an incumbent's investment level in backward compatibility always exceeds the socially optimal one. This conclusion is derived from the fact that an incumbent's commitment to backward compatibility raises socially undesirable switching costs. The relation between "stand-alone valuation" and "network-dependent valuation" in utility function may affect the above divergence. The degree of complementarity between two components would tend to enlarge this disparity, because incumbent's commitment to backward compatibility hurts social welfare in some situations.

In the hardware/software paradigm, we can interpret this complementarity as being derived from continuity of the value of the software based on particular hardware. This interpretation may have an antitrust implication. As pointed out in the above section, divergence of market solution to social optimum may be serious where the software based on the hardware has a long continuity of its economic value. Therefore, in considering antitrust policy on a hardware product, we should pay attention to continuity of the economic value of its software.

We confine ourselves to the very simple model in order to explain incumbent's behavior with regard to backward compatibility clearly. Further research is required in the situation in which new buyers arrive at the new product market. As pointed out in Waldman (1993) and Choi (1994), facing different types of consumers incumbent has various pricing strategies in this setting. So, introducing this factor into our model makes the analysis very difficult. In addition to this, taking the above mechanism, which affects backward compatibility, into account, incumbent may commit to sell its old product to the consumers at the first stage. These problems are very interesting for understanding the determination of backward compatibility level in the presence of network effects. Nevertheless, examining these problems is beyond the scope of this paper.

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