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Incumbent's Incentive under Network Externalities

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Abstract

This paper shows that an incumbent monopolist's incentive confronting a new entrant depends on the degree of product differentiation and the strength of network externality. If products are homogeneous, the incumbent never wants to invite entry regardless of the degree of network externality. On the other hand, if products are differentiated, duopoly profit is higher than the monopoly profit when products are more differentiated and/or the network externality is weak. Conversely, the incumbent has an incentive to deter entry under strong network externality and/or weak product differentiation. A similar result also holds for the compatibility allowance decision.

JEL Classification : D4, L1

Keywords : network externalities, competition effect, demand effect, product differentiation, entry, compatibility, switching cost

1. Introduction.

Network externality, the property that the utility from the consumption of a good increases with the number of other agents consuming the good, is a common feature in many markets such as telecommunications, personal computer hardwares and softwares, etc.[1)] Among the many interesting points regarding the market with network externality is the incentive of an exclusive holder of a technology confronting potential competitors. This occurs precisely because the incumbent can benefit from the competitors in a market with network externality.

Under network externality, competition brings two opposite effects to the incumbent monopolist. One is the standard competition effect which is negative to the incumbent's profit. The other is demand effect, or network effect, which is positive to the incumbent's profit. The demand effect is due to the externality property of the market. As more firms are competing in a market, the number of consumers who buy the product will increase due to a lower price and/or more alternatives to choose from. Then the consumers' willingness to pay, or the market demand, will increase to the benefit of all firms in the market including the incumbent monopolist.

Since competition effect and demand effect work in opposite directions, the incumbent monopolist's incentive confronting new entrants will depend on the relative strength of the two conflicting effects. The monopolist will invite entry if demand effect dominates competition effect, otherwise, it wants to deter competition. Then the question is when does one effect dominate the other.

It's not difficult to find an evidence in a market with network externality which shows that a firm which could have been a monopolist with its new technology, failed to survive even though the technology was highly competitive.[2)] Economists argue that the new technology could have survived if the monopolist had invited entry via open license in the early stages of the market. This is the point in question that the right incentive of a monopolist in a market with significant network externality should be inviting entry.

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1) See Bensen and Farrell(1994), Church and Gandal(1992), Economides(1996), Katz and Shapiro(1985, 1992, 1994), and Liebowitz and Margolis(1994) for the analysis of a market with network externality.

2) Some examples are given in Economides(1996).

However, we are also the witnesses of full-fledged monopolists with an exclusive technology in many markets with network externality. Microsoft in a OS market may be a good example. Then the correct incentive of an incumbent seems to be deterring competition. Furthermore, if the right incentive is opening the market to other firms, the existence of successful monopolists in markets with network externality can hardly be explained.

The conflicting evidence proposes that we need to examine more specific conditions about the network externalities which affect incumbent's incentive against competition. In other words, we need to understand what forces determine the relative strength of the two effects, competition effect and demand effect, in a market with network externality. This paper aims to discuss this issue. I will analyze a market where network externality plays an important role. Particularly the focus is on the incumbent monopolist's incentive against a new entrant: first, to invite entry by giving out free license or deter by closing the license, and second, to allow or disallow compatibility when entry cannot be deterred through licensing strategy.[3)]

The findings of this paper are as follows. We first consider a situation such that entry is possible only by getting a license from the incumbent. If products are homogeneous, the incumbent monopolist never has an incentive to invite entry regardless of the strength of network externality. This is because, if duopoly profit is higher than the monopoly profit, the incumbent monopolist can always duplicate duopoly price at no cost and make even higher profit. If products are differentiated, the incumbent monopolist will invite entry by giving out free license when the network externality is weak and/or the products are more differentiated, and it will deter entry through a closed architecture strategy when the externality is strong and/or products are less differentiated. Furthermore, in case that entry with an incompatible brand is feasible, the incumbent allows compatibility to the entrant when network externality is weak and/or products are more differentiated, while it disallows compatibility under strong network externality and/or weak product differentiation.

The basic model of this paper is similar to that of Katz and Shapiro(1985), which also focuses on the impact of network externality on market equilibrium and the choice of compatibility. However, Katz and Shapiro assume an oligopoly market from the beginning and so do not analyze incumbent's incentive confronting new entrants, which is the main theme of this paper.

3) In this paper, we assume no licensing fee.

Incumbent's incentive to invite entry is also discussed by other economists. Farrell and Gallini(1988) show that, without assuming network externalities, a monopolist with a new product may benefit from (delayed) competition if consumers incur setup costs. When consumers pay high setup costs, they rationally expect that they will be locked-in in the future so that the monopolist might raise price to extract surplus from the consumers. Since such a monopoly incentive is a barrier to attract consumers, the monopolist needs a commitment not to raise future price, and the second-sourcing by strategically inviting competition can be a credible commitment.[4]

Inviting rivals as a second-sourcing of credible commitment is also suggested in the literature on durable goods monopolists. As is well-known, the inability of a monopolist to commit to behavior which is inconsistent with ex-post profit maximization is the main problem of the durable goods monopolists.[5] Therefore, as Ausubel and Denekere(1987) argue, a duopolist can realize higher profit than a monopolist by solving the commitment problem through competition.

Katz and Shapiro(1985) also note the possibility that monopoly profit can be lower than that of a duopoly. However, such a possibility does not rely on the externality characteristic of the industry. Rather, it relies on the special equilibrium concept of fulfilled expectations equilibrium(FEE) and the inability of the monopolist to commit himself to higher sales. The 'unusual result' of Katz and Shapiro is the same phenomenon as that in the literature on the second-sourcing as a commitment through competition.

The most closely related work is Economides(1996). Economides discusses the incentive of an exclusive holder of a technology to share it with competitors in a market with network externalities, and shows that the incumbent has an incentive to invite entry when the network effect is sufficiently strong, but it wants to deter entry under weak externality. It may be somewhat uncomfortable that we have completely opposite results for the same property of network externality. However, it actually helps us, by encouraging us to find out what causes such different results, to better understand the fundamental forces

4) Shepard(1987) similarly analyzes the second-sourcing on demand and shows that licensing competitors can be a way for the innovating firm to make performance (quality) commitment that otherwise would not be credible.

5) Refer to Coase(1972), Stokey(1981), Bulow(1982), and Ausubel and Denekere(1987) for the commitment problem with durable goods monopolists.

affecting incumbent's incentive confronting competitors under network externalities.[6)]

The structure of the paper is as follows. Section 2 describes the basic structure of the model with some remarks on the meaning of 'strong/weak' network externality. A monopoly equilibrium under network externality is given in Section 3 as a reference of remaining analyses. Section 4 describes a duopoly equilibrium with compatibility, and the incentive of the incumbent monopolist regarding entry deterrence will be analyzed in Section 5. In Section 6, another incentive of the monopolist, whether to allow compatibility to the new entrant, will be discussed. Since our results are inconsistent with those of Economides(1996) who studies the same issue as this paper, we will test the robustness of the two conflicting models in Section 7. Section 8 concludes the paper with some remarks.

2. Network Externality.

Following the tradition of product differentiation literature, assume that consumers are uniformly distributed on the [0,1] interval according to her most preferred brand with the total mass of 1. Each consumer buys one unit of the brand that gives her the largest net positive surplus. The net surplus to the consumer who buys one unit of brand that is distant from her most preferred brand by r is $s-tr-p$, where s is the gross surplus of consuming the product, t is the constant marginal disutility of product differentiation, and p is the price of the brand consumed. t represents the degree of product differentiation, or the sensitivity of consumers to product differentiation. We assume that $t\geq 0$ so that the model includes the homogeneous product ($t=0$) as a special case.

Network externality implies that s is a function of network size n. Since consumers make consumption decisions with the expectation of the network size n^e, which is assumed to be common for all consumers, gross surplus s will be a function of n^e as follows.

Assumption 1. $s'(n^e)>0,\quad s''(n^e)\leq 0,\quad s(0)=0^+$

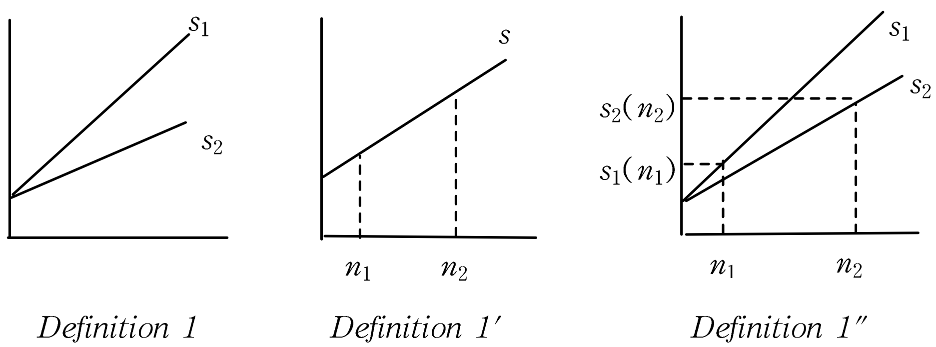
6) The details of the comparison of the two studies are in Section 7.

We assume that $s(0)$, which represents consumer's basic willingness to pay for the product when the expected network size is zero, is strictly positive but negligible. This is to avoid a trivial equilibrium with no consumption and also to highlight the network externality property of a market. Furthermore, we will restrict out attention to the class of externality functions which have the same intercept $s(0)$ and are ranked without any intersections in terms of the strength of the network externality.[7]

Network size n is defined as the total number of customers who consume either the same product or different products with compatibility. This means that a network can be independent with only one brand or it can be a joint network which consists of more than one brand as long as they are compatible to the consumers.[8] We will find a fulfilled expectations equilibrium(FEE) such that consumer's expectation of network size is equal to the actual network size which is determined by the firms' strategic competition in the market.

Before we move on to the formal analysis, some remarks on the meaning of 'strong/weak network externality' are needed since it plays a major role in deriving the main results. Refer to <Figure 1> for the following definitions.

<Figure 1> Meaning of strong/weak network externality



Definition 1. Let s_1 and s_2 be two externality functions (or willingness to pay functions with network externality) which represent the basic nature of the product 1 and 2 respectively. Then product 1 has a stronger network externality property than product 2 if and only if $s_1(n^e) > s_2(n^e)$ for all $n^e > 0$.

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7) The meaning of 'the strength of network externality' will be defined below.

8) To avoid unnecessary complexities, we assume complete compatibility.

Definition 1 describes the dominance among externality functions in terms of strength of network externality. If we compare two different products or markets, for example if we say that the software industry has a stronger network externality than the hardware industry, we are using this ex-ante or potential concept of the strength of network externality.[9)]

Even though Definition 1 seems to be the natural standard to measure the strength of the externality, sometimes people refer to other standards which also seem to have some meaning. To clarify the concept of strong/weak externality, I will compare the above definition with two more seemingly plausible but incorrect standards.[10)]

Definition 1′. Let $n_1 < n_2$ be (expected) network sizes for the same product. Then the network externality is stronger at state n_2 than at state n_1 if and only if $s(n_1) < s(n_2)$, which is always true with a monotonically increasing s.

Definition 1′ may be the relevant meaning of the strength of the externality when we compare two different stages of market growth of the same product. It is a general aspect of a market with network externality that firms have some difficulties to make profit in the early stage of sales due to insufficient network size, but such difficulties disappear once the market becomes full-fledged and sufficient consumers join the network. In this case we may say that network externality is weak in the early stage and it becomes stronger as more consumers join the network following Definition 1′.

Definition 1″. Let (s_1, n_1) and (s_2, n_2) be two different states. State (s_2, n_2) is of stronger externality than state (s_1, n_1) if and only if $s_1(n_1) < s_2(n_2)$.

Definition 1″ is the most general one which combines both Definition 1 and Definition 1′. Market 1 can dominate market 2 in terms of network externality following Definition 1, however, at the same time, state 2 can dominate state 1

9) Surely can it be applied to a given industry when we examine the degree of the network externality.

10) The standard used in Economides(1996) can be another possibility. Economides uses the concept of network externality at the margin to evaluate the strength of network effect. However this is somewhat ambiguous as is discussed later in this paper.

for $n_1 < n_2$. For example, assume that the DVD market is characterized by stronger network externality property than CD market following Definition 1. however, since DVD is a newly started market while CD market is already matured, the network size of DVD is significantly less than that of CD. Given current states of each market, we can say that there is a stronger externality property in CD market than in DVD market following Definition 1″.

Even though both Definition 1′ and 1″ seem to have some relevance, they are not consistent with a fulfilled expectations equilibrium. The point is that network size n depends on s. We cannot compare any arbitrary combinations of (s, n) since there exists unique n which can be supported in equilibrium by s.[11] First assume that, in Definition 1′, n_2 is the equilibrium network size that is supported by s. Then, even though we might observe n_1 in the market, it is only transient and not consistent with consumer's (equilibrium) expectation. Therefore, comparing network externalities with n_1 and with n_2 is meaningless in equilibrium analysis since only one of the two should be observed in equilibrium. If externality is strong following Definition 1, the market will generate a sufficiently large network. This means that the lack of sufficient network at the early stage of a market is only a transient problem which can be overcome by the monopolist itself in equilibrium without help from new competitors.

The same argument can be applied to Definition 1″. If s_1 dominates s_2 according to Definition 1, then $n_1 < n_2$ cannot be true in equilibrium since a large (small) network will be supported as an equilibrium under strong (weak) externality. Since equilibrium network size is determined by s, the state can be rewritten as $(s, n(s))$, a function of s only. Therefore comparing (s_1, n_1) and (s_2, n_2) in Definition 1″ is equivalent to comparing s_1 and s_2, and this implies a return back to Definition 1. To sum, Definition 1 is the standard to evaluate the degree or the strength of network externality. The network size is determined endogenously by s satisfying the equilibrium condition of fulfilled expectations.

It is also needed to clarify the difference between network externality and network effect (or demand effect). As is already mentioned, network externality

11) The uniqueness of the equilibrium network size is due to the concavity assumption for the externality function. If we allow more general externality functions, then there can be multiple equilibrium network sizes. However, even with multiple equilibria, the network size is still endogenously determined by s.

is about the characteristic of a market in general. On the other hand, network effect refers to the benefit from the entrant to the incumbent. It is no doubt that network effect requires network externality. However, it is important to note that what affects incumbent's incentive against entry is not the degree of network externality itself but how strong network effect is.

Network effect can be weak even when the network externality is strong. Network effect is based on two elements; increment of network size due to entry and the strength of network externality. Therefore, even though a market is characterized by strong network externality property, if a new entry does not contribute much in expanding network size, because for example the incumbent has already generated a large network, the network effect will be insignificant. Thus one of the main points in this paper will be understanding how the network effect, therefore the incumbent' incentive against entry, is determined by the strength of network externality.

3. Monopoly.

Consider a monopoly such that firm 1 is at the origin on the [0,1] product line. Consumer r, whose most preferred brand is at r, will buy from the monopoly if and only if the net surplus is positive, that is, $s(n^e) - tr - p \geq 0$. Assume that production cost is zero.[12] Since consumers with $r \leq \frac{s(n^e)-p}{t}$ buy from the monopoly, the optimization problem of firm 1 is as follows.

$$\underset{p}{Maximize}\ \pi^M = \begin{cases} [\frac{s(n^e)-p}{t}]p & \text{for } p > s(n^e) - t \\ p & \text{for } p \leq s(n^e) - t \end{cases}$$

Let p^M be the monopoly price, R^M be the market share of the monopoly, n^M be the actual network size under monopoly, and π^M be the monopoly profit.[13] Proposition 1, with some calculations, summarizes the FEE in the

12) This assumption will be maintained in the duopoly analysis of the following sections.

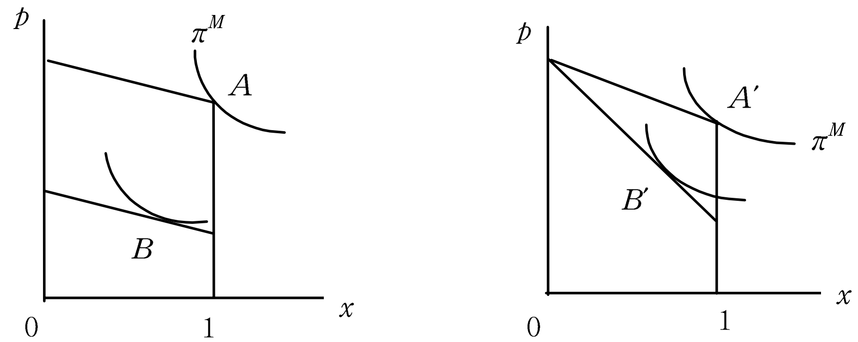
13) In this paper, the market share means the share of the consumers who buy the product.

monopoly market which depends on the strength of network externality.

Proposition 1. The FEE of the monopoly is as follows: (1) if $s(n^e) \geq 2t$, then $n^M = 1$, $R^M = 1$, $p^M = s(n^M) - t$, $\pi^M = s(n^M) - t$. (2) if $s(n^e) < 2t$, then $n^M = \frac{s(n^M)}{2t}$, $R^M = \frac{s(n^M)}{2t}$, $p^M = \frac{s(n^M)}{2}$, $\pi^M = \frac{[s(n^M)]^2}{4t}$.

<Figure 2> FEE under monopoly

strength of network externality　　degree of product differentiation



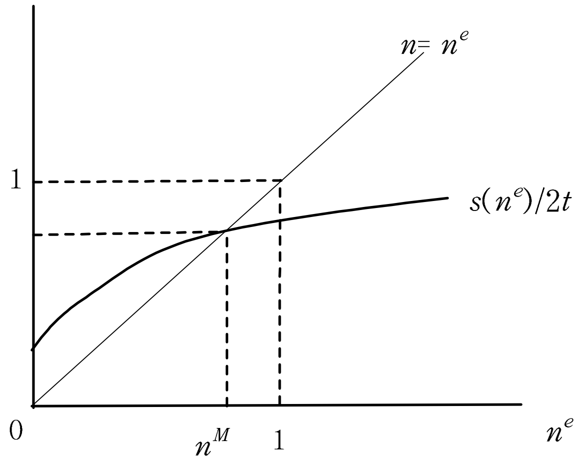
A : strong externality　　A' : weak differentiation

B : weak externality　　B' : strong differentiation

<Figure 2> describes the FEE under monopoly which depends both on the degree of product differentiation and on the strength of the network externality. When the network externality is strong and/or consumers are less sensitive to product differentiation, the monopoly firm captures the whole market even though it charges a high price. However, when the externality is weak and/or consumers are highly sensitive to product differentiation, capturing all the consumers is not optimal since to do that the firm has to lower its price considerably.

When the whole market is covered by the monopolist under strong externality and/or weak product differentiation, consumers' expectation about network size is fulfilled at $n^e = n^M = 1$. On the other hand, when market is not fully covered due to weak externality and/or strong product differentiation, expectation is fulfilled at n^M which satisfies $n^e = n^M = s(n^e)/2t$. <Figure 3> describes the determination of equilibrium network size when $s(n^e) < 2t$, the case of partial coverage.

<Figure 3> **Monopoly equilibrium with partial coverage**



4. Duopoly with Compatibility.

Now assume that firm 2 enters the market at 1 on the [0,1] product space and two differentiated products are fully compatible. With compatibility, the network size n is equal to $R_1 + R_2$, where R_1 and R_2 are the market shares of firm 1 and firm 2 respectively. Let p_1 and p_2 be the prices of two brands and assume that the difference of the two prices is within some boundary to preclude the situation that the whole consumers are captured by one firm to make the market a monopoly.

Assumption 2. $| p_1 - p_2 | < t$

If firms charge high prices then market shares will be small for both firms, however, each firm can be a local monopolist without direct price competition with each other. On the other hand, with low prices, even though firms can induce more consumers, they have to face direct price competition with each other for the marginal consumers. The marginal consumer r is indifferent between the two brands if $s(n^e) - tr - p_1 = s(n^e) - t(1-r) - p_2$ and so the demand for each brand is as follows.

$p_1 + p_2 > 2s(n^e) - t$: local monopoly

$$r \le \frac{s(n^e) - p_1}{t} \quad \text{buy from firm 1}$$

$$r \geq 1 - \frac{s(n^e) - p_2}{t} \text{ buy from firm 2}$$

$p_1 + p_2 \leq 2s(n^e) - t$: direct price competition

$$r \leq \frac{1}{2}[1 + \frac{p_2 - p_1}{t}] \text{ buy from firm 1}$$

$$r > \frac{1}{2}[1 + \frac{p_2 - p_1}{t}] \text{ buy from firm 2}$$

Firms compete with each other a la Bertrand and choose prices to maximize their own profits.

$$Maximize\ \pi_1 = \begin{cases} \frac{1}{2}[1 + \frac{p_2 - p_1}{t}]p_1 & \text{if } p_1 \leq 2s(n^e) - t - p_2 \\ [\frac{s(n^e) - p_1}{t}]p_1 & \text{if } p_1 > 2s(n^e) - t - p_2 \end{cases}$$

$$Maximize\ \pi_2 = \begin{cases} \frac{1}{2}[1 - \frac{p_2 - p_1}{t}]p_2 & \text{if } p_2 \leq 2s(n^e) - t - p_1 \\ [\frac{s(n^e) - p_2}{t}]p_2 & \text{if } p_2 > 2s(n^e) - t - p_1 \end{cases}$$

Let n^C be the network size, and also let R^C, p^C, and π^C be the market share, the price, and the profit of individual firm respectively at the duopoly symmetric equilibrium with compatibility.14) With some calculations, we can find the unique symmetric equilibrium which again depends on the degrees of externality and product differentiation as follows.

Proposition 2. The FEE of the duopoly with compatibility is

(a) if $0 < s(n^e) < t$, then $n^C = \frac{s(n^C)}{t}$, $R^C = \frac{s(n^C)}{2t}$, $p^C = \frac{s(n^C)}{2}$, $\pi^C = \frac{[s(n^C)]^2}{4t}$,

(b) if $t \leq s(n^e) < 3t/2$, then $n^C = 1$, $R^C = \frac{1}{2}$, $p^C = s(n^C) - \frac{t}{2}$, $\pi^C = \frac{1}{2}[s(n^C) - \frac{t}{2}]$,

(c) if $3t/2 \leq s(n^e)$, then $n^C = 1$, $R^C = \frac{1}{2}$, $p^C = t$, $\pi^C = \frac{t}{2}$.

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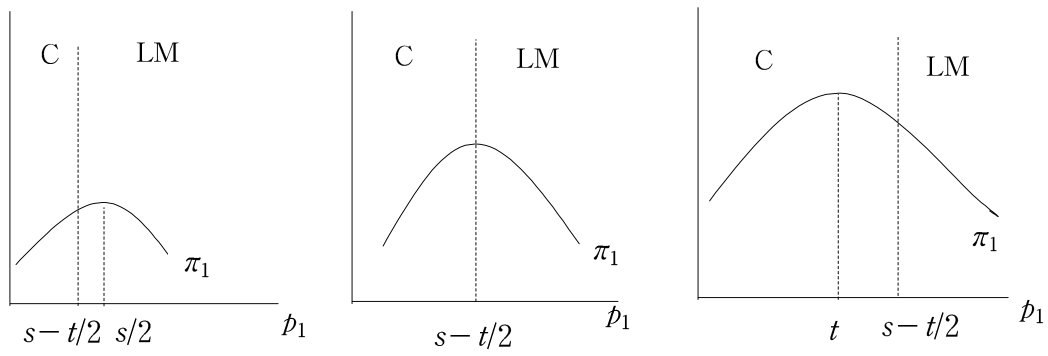
14) We add 'C' to represent 'compatible' case. Later we will use 'IC' for the 'incompatible' case.

<Figure 4> Duopoly equilibrium under network externality

C=competition, LM=local monopoly



(a) $0 < s(n^e) < t$ (b) $t \leq s(n^e) < 3t/2$ (c) $3t/2 \leq s(n^e)$

<Figure 4> explains how firms' optimal choices are affected by the strength of network externality, given t.[15] First, when the externality is weak as in case (a), being a local monopoly with small market share is an optimal strategy to the individual firm since capturing more consumers is too costly because of the low willingness to pay of the consumers. Under local monopoly, markets of competing firms are separated from each other and there are some consumers who do not purchase from either firm.

However even under such a local monopoly situation, since two products are compatible, network size confronted by each firm is not its own market share as in the pure monopoly but the sum of two local monopolists' market shares (see <Figure 5>). Even though the whole market is a duopoly, since there is no direct competition, the new entrant brings positive demand effect to the incumbent monopolist without invoking negative competition effect. Therefore, the incumbent firm 1's price, market share, and profit become higher than under pre-entry pure monopoly.[16]

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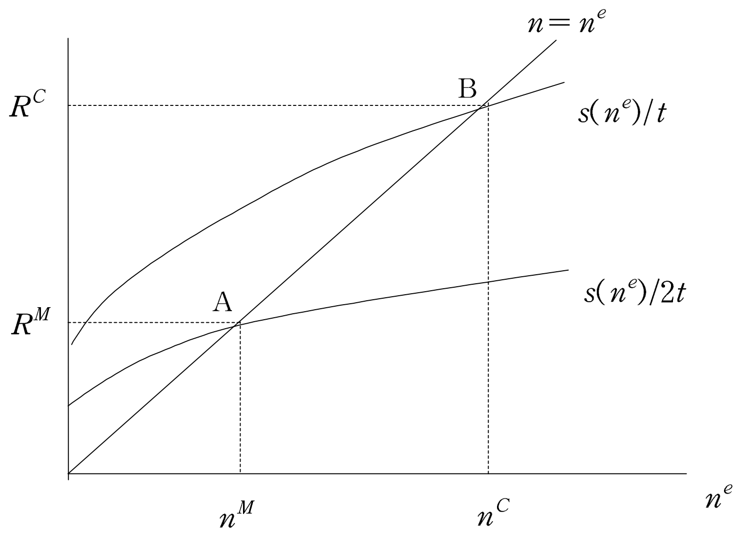
15) Since the implication of product differentiation can be easily derived when necessary, for simplicity, we will focus on the network externality property assuming t is fixed.

16) $p^C = s(n^C)/2 > s(n^M)/2 = p^M$. $\pi^C = p^C R^C > p^M R^M = \pi^M$ since $p^C > p^M$ and $R^C > R^M$.

<Figure 5> Local monopoly under duopoly

A : pure monopoly   B : local monopoly under duopoly



$n^M = R^M$, $n^C = 2R^C$, $R^C > R^M$

As the network externality becomes stronger as in case (b), firms expand their own markets to exploit the higher willingness to pay of the consumers. However since the network externality is not yet strong enough to offset competition effect, firms expand their own markets only up to the point where the rent from the local monopoly is fully extracted while direct price competition is not triggered.

Finally, when the network externality becomes strong enough as in case (c), price competition between the two firms is activated to induce more consumers with high willingness to pay. Firms cannot expand their own markets simply because the market is already fully covered, however, high willingness to pay of the consumers makes firms involved in direct price competition with each other. Note that even though they are involved in a direct price competition, which is not activated in case (a) and (b), the equilibrium market price in (c) is higher than the market price in (a) and (b). The reason firms are involved in direct price competition in spite of the fact that their market shares cannot be expanded any further is because of the high willingness to pay by the consumers.

5. Incumbent's Incentive to Deter or Invite Entry.

It is time to check the incentive of the incumbent confronting a new entrant. It is obvious that the incumbent has an incentive to deter entry when the new product is incompatible with existing one. This is because, under incompatibility, a new entrant brings no positive demand effect but only gives negative competition effect to the incumbent.[17] Therefore we will consider a case with compatibility.

To repeat, the incentive of the incumbent to deter or invite entry depends on the relative size of the competition effect and the demand effect. Then when does one effect dominate the other? The answer depends on the strength of the network externality and the degree of product differentiation. Let us first consider the case of homogeneous products.

Proposition 3. If products are homogeneous, or equivalently if $t=0$, the incumbent monopolist never has an incentive to invite entry regardless of the strength of the network externality.

<Proof> Assume that the incumbent wants to invite entry, that is, $\pi^M < \pi^C$. Then the incumbent can make even higher monopoly profit than π^C by choosing p^C, instead of p^M, as the monopoly price. At p^C, the monopoly profit will be $2\pi^C$, which implies that the incumbent monopolist will not invite entry. Therefore, $\pi^M < \pi^C$ cannot hold when the products are homogeneous. Q.E.D.

Proposition 3 is very intuitive. If products are homogeneous, the incumbent monopolist can always duplicate the duopoly market equilibrium. Therefore, if duopoly profit is higher than the monopoly profit, the incumbent can make even higher profit by simply duplicating duopoly equilibrium price and capturing the whole market without inviting entry. Since incumbent's incentive against entry is trivial with homogeneous markets, we will strictly assume $t>0$ from now on.

Proposition 4. Assume $t>0$. Then $\pi^M \geq \pi^C$ for $s \geq t$ (equality holds when $s=t$) and $\pi^M < \pi^C$ for $s < t$.

17) If incompatible, then the issue of allowing free license is also meaningless.

<Proof> (1) $0 < s \le t$: $\pi^C = \frac{[s(n^C)]^2}{4t} > \frac{[s(n^M)]^2}{4t} = \pi^M$, since $n^C > n^M$ for $s \in (0\, t]$.

(2) $t \le s < 3t/2$: $\pi^C = \frac{1}{2}[s(1) - \frac{t}{2}]$ and $\pi^M = \frac{[s(n^M)^2]}{4t}$. First $\pi^C = \pi^M = t/4$ when $s = t$. Furthermore, while the slope of π^C is constant at $1/2$ within the whole range, the slope of π^M is $1/2$ at $s = t$ and then increasing with s in $[t, 3t/2)$. Therefore $\pi^M \ge \pi^C$ for $s \in [t, 3t/2)$ and the equality holds at $s = t$. (3) $3t/2 \le s < 2t$: $\pi^M = \frac{[s(n^M)]^2}{4t} \ge \frac{9t}{16} > \frac{t}{2} = \pi^C$. (4) $2t \le s$: $\pi^M = s(1) - t \ge t > t/2 = \pi^C$. Q.E.D.

Proposition 4 says that, in a differentiated market, if network externality is strong and/or products are less differentiated, monopoly profit is larger than the duopoly profit and so the incumbent monopolist has an incentive to deter entry, and if network externality is weak and/or products are highly differentiated, the monopolist incumbent has an incentive to invite entry since duopoly profit is larger than the monopoly profit.

Again, fix t and focus on the network externality without loss of any relevance. When the network externality is strong, the incumbent monopolist already captures full market so that the new entrant's contribution to the network expansion is nothing.[18] It means that competition effect is stronger than the network effect, and so the incumbent wants to deter entry.

On the other hand, if the network externality is weak, the incumbent monopolist has only a partial coverage. It is because consumers have low willingness to pay so that capturing full market by lowering price is too costly. In this situation, the network is expanded significantly by a new entrant without invoking serious price competition since the post-entry market would be a local monopoly under weak externality.

The point in Proposition 4 is which is more desirable to the incumbent monopolist; expanding network by itself or getting benefit from a new entrant? The common mistake is from the confusion between network externality and network effect; if network externality is strong, the benefit from additional firm (network effect) is high enough to offset competition effect, therefore the incumbent has an incentive to invite entry. However, as already emphasized before, strong network externality doesn't mean strong network effect. Actually,

18) No network effect from the new entrant may be too extreme. However even though 'full coverage' is replaced by 'substantial market share' and 'no network effect' by 'negligible network effect', the idea of the proposition is still valid.

the opposite is the truth.

Strong network externality implies high willingness-to-pay of the consumers. Then the monopolist can easily expand the market so that the additional contribution of the new entrant to the network size, that is network effect, will be insignificant. On the other hand, with low willingness to pay by the consumers due to the weak network externality, expanding network by itself is too costly to the monopolist so that it will rather invite a new entry to enjoy the network effect from the rival.[19)]

Proposition 4 has an important implication in licensing. Consider a situation that new firms can enter the market only under the provision of the compatibility technology by the incumbent monopolist. Assume further that there is no licensing fee to avoid unnecessary complication. Proposition 4 shows that the incumbent monopolist, who is the exclusive holder of a technology, will adopt a closed architecture strategy when network externality is strong (therefore network effect is weak), and an open architecture strategy when network externality is weak (i.e., network effect is strong).[20)]

6. Incumbent's Incentive to Allow or Disallow Compatibility.

What if the incumbent cannot deter entry but can only decide whether it allows compatibility to the competitor or not?[21)] To find conditions for the incumbent's incentive to allow or disallow compatibility, assume that firm 1 and

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19) This is a different second-sourcing from Farrell and Gallini(1988), where it is a way to make commitment credible to the consumers. In our analysis, since consumers' expectations are not endogenously determined, credible commitment to make consumers' expectations more favorable to the firm's profit is irrelevant.

20) It is a remaining question whether this result is consistent with reality. One interesting observation is that open architecture strategy is more common in hardware markets than in software markets. This may be because softwares have a stronger externality property than hardwares. Such a hypothesis is based on the observation that the compatibility of softwares already assumes that of hardwares, but the converse is not true. However, we need empirical evidence before concluding about the relative strength of the externality between two different industries.

21) We assume that compatibility is allowed without any fee to the new entrant, and it is optimal for the entrant to accept compatibility when it is allowed.

firm 2 are producing incompatible products, maintaining the maximum differentiation assumption as before.

When we consider an incompatible case, consumers' switching cost emerges as an important factor.[22] Assume that consumers have to incur $c>0$ in addition to p_2 as a switching cost, or search cost, to buy from the new entrant.[23] It is innocuous to assume that the surplus from the existing product is known to all consumers. Those who are consuming the existing brand should know the surplus they are enjoying now, and even those consumers who do not consume the product might have enough information about the product via various channels such as direct or mouth-to-mouth advertising, etc. Being compared with the existing product, the new entrant, particularly when its product is incompatible with the existing one, has a natural disadvantage in informing its own product to the consumers.

Under incompatibility, a new entrant brings no demand effect so that only competition effect matters. However, it is wrong to expect that the incumbent has a clear incentive to allow compatibility to benefit from the network effect, which does not exist under incompatibility. Although there is no positive demand effect under incompatibility, the switching cost, which is negligible in compatibility case, gives the incumbent a strategic advantage to make the competition effect less severe than under the compatible case. Then the issue to the incumbent is whether it should allow compatibility expecting positive demand externality but also strong negative competition effect from the new entrant, or should it disallow compatibility expecting no positive demand externality but weak negative competition effect from the new entrant. The answer again depends on the strength of the network externality.

Proposition 5. When entry cannot be deterred the incumbent will allow compatibility under weak network externality and disallow compatibility under strong network externality.

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22) It is true that even though the products are compatible, as long as they are not homogeneous, there might be some switching cost between the two products. However, we can assume that switching cost between compatible products is much smaller compared to that between incompatible products.

23) If there is no switching cost, then the analysis becomes trivial. The incumbent always wants to allow compatibility regardless of the strength of the network externality.

<Proof> To avoid unnecessary duplication with the compatible duopoly case, we will just sketch the proof. As in the compatible case, the duopoly equilibrium with incompatibility depends on the degree of network externality. First consider the case with weak externality. In this case, duopoly equilibrium becomes a local monopoly by each firm. Firm 1's profit is the same as the standard monopoly profit which is already proved to be less than the local monopoly profit under compatible duopoly, that is, $\pi_1^{IC} = \pi^M < \pi_1^C$.

Next consider the case that network externality is strong enough to make the market fully covered by the two products. The marginal consumer r is indifferent between the two product if $s(n^e) - tr - p_1 = s(n^e) - t(1-r) - p_2 - c$. Then firms' profits are as follows.

$$\pi_1 = [\frac{1}{2} + \frac{(s(n_1^e) - p_1) - (s(n_2^e) - p_2 - c)}{2t}]p_1$$

$$\pi_2 = [\frac{1}{2} - \frac{(s(n_1^e) - p_1) - (s(n_2^e) - p_2 - c)}{2t}]p_2$$

After some calculations, we find an asymmetric duopoly equilibrium with incompatibility and switching cost when the externality is strong.

$$p_1^{IC} = t + \frac{s(n_1^{IC}) - s(n_2^{IC}) + c}{3}$$

$$p_2^{IC} = t - \frac{s(n_1^{IC}) - s(n_2^{IC}) + c}{3}$$

$$n_1^{IC} = \frac{1}{2} + \frac{1}{2t}[\frac{s(n_1^{IC}) - s(n_2^{IC}) + c}{3}]$$

$$n_2^{IC} = \frac{1}{2} - \frac{1}{2t}[\frac{s(n_1^{IC}) - s(n_2^{IC}) + c}{3}]$$

Firm 1 has a larger market with higher price than firm 2 due to the strategic advantage coming from the switching cost c. Firm 1's profit is $\pi_1^{IC} = p_1^{IC} n_1^{IC} = [t + \frac{s(n_1^{IC}) - s(n_2^{IC}) + c}{3}][\frac{1}{2} + \frac{1}{2t}(\frac{s(n_1^{IC}) - s(n_2^{IC}) + c}{3})]$, and since $s(n_1^{IC}) - s(n_2^{IC}) + c > 0$, $\pi_1^{IC} > t/2 = \pi_1^C$. Q.E.D.

7. Robustness: Comparison with Economides(1996).

Economides(1996) discusses the incentive of an exclusive holder of a technology to share it with competitors in a market with network externalities. He focuses on the stable fulfilled expectations equilibrium, and shows that, if network effect is sufficiently strong, a quantity leader has an incentive to invite entry and license his technology without charge. He argues that the result also holds under a Cournot competition model, and expects that it will also hold under price competition if there is sufficient product differentiation.

To find out the sources that cause different forecasts regarding incumbent's incentive in Economides and in this paper, recall the basic model and the main result of Economides as follows. Network externality is incorporated in the inverse demand function $P = A - Q + f(S)$, where P is the market price, A is a positive constant, Q is the total output level, $f(S)$ is the network externality function, and S is the expected size of sales. He analyzes a Stackelberg competition, where the incumbent monopolist is a quantity leader, and extends it to the Cournot competition model. The main result of the paper is that the profit of the incumbent (an exclusive holder of a technology) is increasing with the number of competitors if the network externality is strong at the margin in the sense that $f'(S^*) > \frac{2n}{(2n+1)}$ for the Stackelberg competition and $f'(S^*) > \frac{(n-1)}{n}$ for the Cournot competition, where S^* is the equilibrium network size.

Several questions are immediate. First, the meaning of 'strong (weak)' network effect is ambiguous. For example, as given in Economides, assume that $f(S) = bS,\ b < 1$. This means a constant marginal network effect, however, it is interpreted as 'strong' with a small n and as 'weak' with a large n (for example, assume $b \in (2/3, 4/5)$, then the network effect is 'strong' when $n = 1$ and 'weak' when $n = 2$). This example shows that the strength of network effect in Economides is not a characteristic of a market itself because the same externality function becomes 'strong' or 'weak' depending on the market structure.

Second, the predictions about incumbent's incentive based on the marginal concept of network externality is misleading. To see this, reconsider our main result. When network externality is strong, the incumbent monopolist already builds a large network to exploit consumers' high willingness to pay. This implies that the network effect, the contribution of the new entrant to the network size, is insignificant so that the incumbent wants to deter entry to avoid negative competition effect. However, this logic holds even under the strong marginal network externality following Economides. It is because the network itself does not increase significantly (actually it does not increase at all when the network effect is strong in our analysis) with a new entry so that the network effect, which depends both on the marginal externality and on the increment of network size, is negligible to the incumbent. The incumbent has an incentive to deter entry under strong externality at the margin following Economides, which is contradictory to the main result of Economides himself.[24]

Third, the model is not satisfactory in explaining the existence of a successful monopolist, such as Microsoft, in a market with significant network externality. Assume again a linear externality function. Then the incumbent's incentive to invite entry is monotonically decreasing with the number of firms n (according to the interpretation of Economides, the network effect becomes weaker as more firms enter). This means that the existing monopoly did not invite entry at the moment of the strongest incentive to invite entry or when the network effect was the strongest. This was because, according to Economides, even the strongest network externality was weak! This is somewhat self-contradictory since it means that there can exist a monopoly in a market with significant network externality only when the network externality is significantly weak even at the moment when the network externality is the strongest.

Fourth, even though Economides argues that the main result from the Stackelberg model holds under a Cournot model, there is a critical problem in such an extension. Recall that the incumbent has an incentive to invite entry if $f'(S^*) > \frac{(n-1)}{n}$ in a Cournot competition model. However when the market is a monopoly, which means that $n=1$, then the above condition is satisfied for any $f(S)$ with $f'(S) > 0$ regardless of the degree of network effect. This means that, in any markets with network externality, the monopoly always invites entry under Cournot competition game.

Finally, the main result of Economides is not robust as is argued by Economides. It is already mentioned that there is a problem with a Cournot

24) Economides doesn't notice the difference between network externality and network effect. He actually uses these two concepts as the same one.

competition model. Furthermore, it is also proved in this paper that, again contrary to the expectation of Economides, the main result does not seem to hold under a price competition model with product differentiation.

All of the problems in Economides can be explained by Proposition 3 in this paper. Economides assumes homogeneous products. However, as is proved in Proposition 3, if products are homogeneous, the degree of network externality is irrelevant in analysing incumbent's incentive against entry since the incumbent can always duplicate duopoly price. This means that if duopoly brings a higher profit than monopoly, the incumbent monopolist can make even higher profit by simply duplicating duopoly price without allowing entry. Therefore, the incumbent's profit under competition cannot be greater than the monopoly profit under homogeneous case.

On the other hand, if the entry brings a differentiated product, duplication is not costless to the incumbent monopolist any more. It is because duplication implies introducing another brand, and so incurs some setup cost to the incumbent. Assume $\pi^C > \pi^M$ under product differentiation. In this case, if $2\pi^C - F > \pi^M$, then again the incumbent will not invite entry, but will introduce another brand by itself and charge p^C for both brands. In this paper, to exclude such a possibility, not because it is unrealistic but to focus on the main subject of this paper, we will assume that each firm chooses only one brand.

8. Concluding Remarks.

We can summarize this paper by two major understandings about the market competition under network externalities. First, the impact of new entry on incumbent's profit depends both on the degree of product differentiation and on the strength of network externality. If products are homogeneous, the incumbent will never invite entry, regardless of the strength of network externality. This is because the incumbent monopolist, if necessary, can duplicate any oligopoly market outcome without any cost. On the other hand, if products are differentiated, the answer depends on the relative strength of the two forces, network externality and product differentiation.

Second, under given degree of product differentiation, network effect which determines incumbent's incentive against entry is inversely related with the network externality. If network externality is strong, the incumbent expands network significantly by itself so that the additional contribution by the new entry to the network size, therefore the network effect, is insignificant. In this case, the incumbent will have an incentive to deter entry to avoid negative competition effect. On the other hand, if network externality is weak, it is too costly for the incumbent to expand network by itself. Therefore, it will be optimal for the incumbent to invite entry to enjoy the benefit of network effect which is enough to offset competition effect.

As concluding remarks, we can think of several research agenda for the better understanding of markets with network externality. First, as this paper attempted, we need a clear standard to measure the degree of network externality. Second, a dynamic model seems to be more appropriate for the analysis of a market with network externality. This is because the network cannot be built instantaneously but should be accumulated over time. The static models, like this paper and Economides, cannot explain successfully the different stages of market development under network externality, which is an important aspect in reality. Finally, endogenous formation of consumers′ expectation about network size is another interesting issue. If the incumbent monopolist fails to make large network credible to the consumers, then the same second-sourcing as a commitment as in Farrell and Gallini(1988) will be an incentive of the incumbent. This is what Katz and Shapiro(1985) refers to in his pioneering work in the area of network externality.

References

Ausubel, L. and Denekere, R. "One Is Almost Enough for Monopoly." *RAND Journal of Economics*, Vol. 18 (1987), pp. 255-274.

Bensen, S. and Farrell, J. "Choosing How to Compete: Strategies and Tactics in Standardization." *Journal of Economic Perspectives*, Vol. 8 (1994), pp. 117-131.

Bulow, J. "Durable Goods Monopolists." *Journal of Political Economy*, Vol. 90 (1982), pp.314-332.

Church, J. and Gandal, N. "Network Effects, Software Provision, and Standardization." *Journal of Industrial Economics*, Vol. XL (1992), pp. 85-104.

Coase, R. "Durability and Monopoly." *Journal of Law and Economics*, Vol. 15 (1972), pp. 143-149.

Economides, N. "Network Externalities, Complementarities, and Invitations to Enter." *European Journal of Political Economy*, Vol. 12 (1996), pp. 211-233.

Farrell, J. and Gallini, N. "Second-Sourcing as a Commitment: Monopoly Incentives to Attract Competition." *The Quarterly Journal of Economics,* Vol. 103 (1988), pp. 673-694.

Katz, M. and Shapiro, C. "Network Externalities, Competition, and Compatibility." *American Economic Review*, Vol. 75 (1985), pp. 424-440.

Katz, M. and Shapiro, C. "Product Introduction with Network Externalities." *The Journal of Industrial Economics*, Vol. XL (1992), pp. 55-83.

Katz, M. and Shapiro, C. "Systems Competition and Network Effects.", *Journal of Economic Perspectives*, Vol. 8 (1994), pp. 93-115.

Liebowitz, S. and Margolis, S. "Network Externality: An Uncommon Tragedy." *Journal of Economic Perspectives*, Vol. 8 (1994), pp. 133-150.

Shepard, A. "Licensing to Enhance Demand for New Technologies." *RAND Journal of Economics*, Vol. 18 (1987), pp. 360-368.

Stokey, N. "Rational Expectations and Durable Goods Pricing." *Bell Journal of Economics*, Vol. 12 (1981), pp.112-128.