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Bottleneck Monopolies and Network Externalities in
Network Industries: Introduction to Network Economics

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Abstract:

Network industries have played an important role in the modern economy, but special considerations are necessary for regulatory reforms of them. Two main points for understanding these industries are bottleneck monopolies and network externalities. In this paper, we will propose benchmark models for analyzing them. The most important conclusions obtained from this study are: first, network competition is better than bottleneck monopolies, and we can control the bottleneck not by unbundling, but by price-cap regulation; second, although the negative aspects of network externalities have been overemphasized, they do not always have the characteristics of market failures in regard to interlinking.

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1. Introduction

As a result of rapid innovation, network industries, such as telecommunications, electric power, city gas, and railway, have played an important role in determining a country's economic growth. The USA and the UK have rapidly furthered regulatory reforms in these industries, whereas the pace of Japan's reform, which used to be quite slow, has finally overtaken other countries. We can summarize the regulatory reforms of Japan's network industries as follows:

- The telecommunications industry: The Nippon Telegraph and Telephone Public Corporation was privatized as the Nippon Telegraph and Telephone Corporation (NTT) in 1985, and New Common Carrier (NCC) has also commenced business since 1987. NCC has steadily improved its share of the long-distance toll market, and this figure has reached more than 50%. NTT was reorganized as one long-distance telephone company and two regional telephone companies under a holding company system in 1999, and fair competition in this industry has significantly progressed.
- The electric power industry: This industry had been regionally monopolized, and the first regulatory reform was introduced in 1995, when a yardstick assessment of the operating costs was imposed on nine incumbent power companies, and regulation of entry to the market of power generation was abolished. Furthermore, a second round of regulatory reform was

implemented in 2000, when about 30% of the retail market was liberalized.

Further expansion of this liberalization policy is now being discussed.

- The passenger transport industry: The Japan National Railway was privatized in 1987, when six passenger and one freight Japan Railway (JR) companies were established. The running of the business has stayed on track since privatization. Turning to the air transport industry, regulation of entry (a double-tracking/ triple-tracking system) was abolished in 1992, and price regulation was also relaxed significantly.

Interestingly, several attempts have been made to grasp the economic effects of the regulatory reforms in Japan's network industries.

- The annual increases in total factor productivity (TFP) caused by the regulatory reforms amount to 3.4% in the telecommunications and 1.1% in the air transport business. In addition, the annual increases in labor productivity are 1.2% in the electric power industry and 2.4% in the city gas industry (Cabinet Office, 2001a).
- Turning to the consumer benefits brought about by the regulatory reforms, official figures until 2000 show that the benefits reached 4.1% of GDP (15.7 trillion yen), and even the figure that was calculated only in 2000 was 0.19% of GDP (1.4 trillion yen) (Cabinet Office, 2001b).

It is natural that prices temporarily drop if markets are liberalized. What is more

important, however, is whether prices remain stable, innovation occurs in succession, or stable supply is assured. From these points of view, we should not ignore some lessons that may demonstrate the negative results of deregulation, such as the re-oligopolization of the air transport market in the USA, the crisis in the power supply in California, and a succession of railroad accidents in the UK.

Why are special considerations necessary for regulatory reforms in network industries? This question is to be studied from two points of view. The first point is what is called a *bottleneck monopoly*. Network infrastructures, such as local telecommunications loops, power transmission lines, gas pipelines, and railroads, are essential for supplying services to customers in these industries. Therefore, in the past a firm could not enter into a market without holding enormous network facilities. However, it is currently becoming possible to enter into some areas of network industries, such as the long-distance toll market, power generation, and refining of natural gas. Accordingly, the regulatory reforms to open up bottlenecked facilities to all competitive providers have certainly become important matters of policy.

The second point addresses *network externalities*. Network externalities, which mean that users of a service benefit when more people use it, frequently exist in network industries. To take an example from telecommunications, since the aim of a user is not to join a network but to communicate with more people in the network, it is advantageous for him to choose a larger-scale network. Thus, it is desirable that

networks are interconnected and a network of networks is formed so that network externalities work effectively and efficiently. It is a matter of policy, therefore, to investigate the conditions under which the network autonomously expands.

Bottleneck monopolies represent economies of scale on the supply side, whereas network externalities do so on the demand side. It is important to note that some positive feedback may occur under a system with economies of scale; in this way, an inferior technology might spread, or remain for a long period, causing a social inefficiency. Moreover, since the system is nonlinear, it is very difficult to predict precisely what results an industrial policy will bring about. To sum up, network industries are very complex. This paper will also examine these characteristics of network industries.

The paper comprises the following six sections. Section 2 describes how network industries were deregulated following the contestable market theory, and explains the meaning of incentive regulation. Section 3 reviews previous research on bottleneck monopolies and shows development of an analytical model. Section 4 summarizes previous arguments on network externalities and proposes an analytical model. Section 5 discusses various topics such as industrial fusion and the complexity of network economy, and Section 6 presents the conclusion.

2. From Regulation to Competition

This section provides an outline of the regulation and competition in network industries.

2.1 Public utilities regulation

There are two types of *direct regulation*, which means that the government legally restricts the structure of a market and the behaviors of private enterprises: *economic regulation*, which aims to avoid allocative inefficiencies, and *social regulation*, which aims to secure the safety, health, and environment of citizens. A *natural monopoly*, as well as *asymmetric information*, provides a ground for economic regulation. Naturally monopolistic industries are represented in public utilities such as telecommunications, electric power, city gas, and railroad industries, which required enormous amounts of fixed capital and are necessities in our lives¹. *Public utilities law* gives the government the legal authority to restrict the entry-and-exit of a firm in order to avoid destructive competition and determines the price and investment needed for improving allocative efficiencies.

Theoretically, the government can solve the market failures of a natural monopoly

¹ See Braeutigam (1989) for further details on public utilities regulation.

by implementing public utilities regulations, attaining the first-best, or at least the second-best, level of social welfare. However, several types of government failure have been pointed out in various studies. The first type is *X inefficiency* (H. Leibenstein), which is the difference between the efficient behavior of a firm assumed by economic theory and the observed behavior in practice when the cost is promised to be reimbursed by the government. The second is *Averch-Johnson effect*, which insists that since the allowed profit is predicated on the rate base (RB), the firm has an incentive to augment its capital stock. The third is *rent seeking* (R. Posner), which represents the expenditure of resources in order to bring about an uncompensated transfer of services from another person to one's self as the result of a favorable decision on some public policy.

2.2 Contestable market theory

The contestable market theory was developed by Baumol and his colleagues in the 1970s to investigate sustainable industrial structure, the characteristics of the multi-goods cost function, and the definition of cross-subsidization, among others. Baumol, Panzar and Willig (1982) compiled all related works into one book. Along with criticism of the government failures in those days, this theory is said to have provided the theoretical grounds for deregulation. One major point of the contestable market theory can be summarized as follows:

- Contestability theorem: If a market is contestable, socially desirable welfare can

be automatically attained as a result of the potential pressure of new entrant even in a traditionally regulated industry; consequently, no public utilities regulation is necessary².

The contestable market theory was considered as a benchmark model for deregulating public utilities. A representative opinion can be seen in the following quotation: “The Contestability benchmark proves highly useful as a framework for evaluating policies and outcomes. Under the contestability framework, entry and price regulation is deemed inappropriate in industries which do not have system-wide natural monopoly characteristics. On this criterion, brokerage, airline, trucking, long-distance telephone and terminal equipment should not be regulated” (Bailey, 1986 p.1).

Nevertheless, the influence of the contestable market theory in the academic world did not last long, because it countered various criticisms from conceptual, theoretical, and empirical points of view. Typical criticisms are as follows:

- Conceptual criticisms: A contestable market does not always have a sustainable equilibrium (Vickers and Yarrow, 1988); the concept of contestability does not

² The conditions for a perfect contestable market are: (1) all firms have homogeneous cost and demand functions, (2) the entry-and-exit of all firms are completely free, that is to say that ‘sunk costs’ do not exist, (3) there is a time lag for an incumbent firm to change its price, and (4) there is no time lag for consumers to react to a price difference (Dixit, 1982).

accurately reflect the presumed *ultra free-entry conditions* (Shepherd, 1984, 1995); it also contradicts the economies of scale (Weitzman, 1983).

- Theoretical criticisms: The contestability theorem is not robust in an imperfect contestable market where the assumptions of the reaction lag of an incumbent firm and zero sunk cost are partially satisfied (Schwartz and Reynolds, 1983; Schwartz, 1986). Baumol et al. at last accepted these criticisms (Baumol, Panzar and Willig, 1983).
- Empirical criticisms: passenger fares are positively correlated with market share (Keeler and Abrahams, 1981; Graham, Kaplan and Sibley, 1983; Bailey, Graham and Kaplan, 1985; Call and Keeler, 1985; Town and Milliman, 1989); passenger fares also depend upon whether a competitor actually exists (Moore, 1986; Morrison and Winston, 1987; Baker and Pratte, 1989). The above observations contradict the contestability theorem.

2.3 Incentive regulation

A simple deregulation theory based on the contestability theorem had lost the support in the 1980s. Instead, a regulatory reform movement that synthesizes the market failures and the government failures became popular in the 1990s. One representative example of regulatory reforms is *incentive regulation*, which means that the government should delegate a firm the authority to determine public charges to some extent so that a desirable economic performance is to be achieved (Sappington and Weisman, 1996).

There are several types of incentive regulation, outlined as follows:

- Profit sharing regulation: A firm is permitted to obtain a part of the excess profit when it earns more than a fair rate of return; thus, this firm will have the incentive to improve its management efficiency³. Given that Π is the gained profit, Π_0 is a benchmark profit, Π_a is the realized profit, and α is a distribution weight, we obtain $\Pi = \Pi_0 + \alpha (\Pi_a - \Pi_0) = (1 - \alpha) \Pi_0 + \alpha \Pi_a$ ⁴.
- Price cap regulation: The government sets a ceiling on the average price that can be charged by a firm, but the firm can rebalance freely the prices within this constraint⁵. Given that P_t represents the average price at period t , RPI is the rate of the price index, X is the rate of rise of productive efficiency, and Z is the adjustment rate of other factors, we obtain $P_t = P_{t-1}(1 + RPI - X + Z)$ ⁶.
- Yardstick regulation: economic performances of regional monopolies are compared with each other, so that an indirect competition works⁷. Japan's

³ Profit sharing regulation was actually adopted in the US electricity industry after the war. Also, the sliding scale method used in the Japanese city gas industry is another example.

⁴ Leob and Magat (1979) provides a theoretical foundation for profit sharing regulation, arguing that if the government gives the excess profit to a firm, the first-best resource allocation can be attained.

⁵ Price cap regulations have been actually introduced in a lot of countries since the Littlechild Report was published in 1983.

⁶ Vogelsang and Finsinger (1979) provide a theoretical foundation for price cap regulation, arguing that a capped price will finally converge towards the second-best price.

⁷ Shleifer (1985) provides a theoretical ground for yardstick regulation, arguing that yardstick competition brings about desirable resource allocation.

private railway and city bus industries have adopted standard cost comparisons, which are examples of yardstick regulation.

- Franchise bidding: A business license is put up for auction⁸. A famous example in the world is the 3G (third-generation mobile phone) airwave auction.
- Bayesian mechanism design: The government offers a self-selecting contract to a firm to solve the asymmetric information problem⁹.

Incentive regulation has played an important role in present regulatory reforms. There have been some attempts to measure the economic effects of incentive regulation¹⁰, although it is still difficult to determine whether incentive regulation certainly guarantees the success of the restructuring of network industries. The first reason for this is that incentive regulations described above have their own respective faults, such as the difficulty in determining the X-term in price cap regulation or the ambiguity of subjective probability under the Bayesian mechanism. The second reason

⁸ Demsetz (1968) provides a theoretical foundation for franchise bidding, arguing that even an incumbent firm cannot set a monopolistic price because it is afraid that an entrant will offer a cheaper price when a business license is bid for. It is interesting to note that this idea anticipates the contestable market theory.

⁹ Bayesian regulation can be classified into two types: (1) the adverse selection model in which firm's type is private information (Baron and Myerson, 1982), and (2) the moral hazard model in which firm's behavior is private information (Laffont and Tirole, 1986).

¹⁰ The price level is lower in the states where incentive regulations have been adopted than in those where traditional rate-of-return regulations are still in effect (Donald and Sappington, 1995). Also, the price levels are lower in the states whose experiences of deregulation are longer than in those where traditional regulations are still in effect (Kastner and Kahn, 1990).

is, more importantly, that the previous research on incentive regulation has not fully investigated the inherent characteristics of the network industries on both the supply and demand sides: bottleneck monopolies and network externalities. We will go on to study these characteristics in the following sections.

3. Bottleneck Monopoly

This section first previews the characteristics of the supply side of network industries, namely the bottleneck monopoly and, second, proposes a model to analyze this problem.

3.1 Preview of bottleneck monopoly

One major problem of liberalization or deregulation in network industries, such as telecommunications, electricity, city gas and railroad, is that competition does not work effectively because the network facilities have the characteristics of a bottleneck or *essential facilities*. The essential facilities doctrine originated in commentary on US Antitrust law (cf. the Supreme Court 1912 *Terminal Railroads* decision) and has featured prominently in a number of decisions made by competition authorities around the world (Sidak and Spulber, 1998). There are two types of open-access policies for essential facilities:

- Behavioral regulation: The government determines or intervenes in the various decisions of a bottleneck monopoly, including entry, exit, price, investment, side-business, and even technical standards. An example is *asymmetric regulation*: only the dominant firm whose market share is sufficiently high is asymmetrically regulated.
- Structural regulation: The government stipulates specific terms for a firm to enter and exit a market, and designs the market structure itself. Examples are the divestiture of the US telecommunications industry or the unbundling of the UK electric power industry.

It is difficult to determine which is more desirable in general -- behavioral regulation or structural regulation. To put it another way, if we can set an access charge adequately, which is the wholesale price to be paid to a bottleneck monopoly for an interconnection, behavioral regulation is satisfactory enough and structural regulation is not necessary; and vice versa.

At this point, we suppose a bottleneck monopoly, X , which has the long-distance telecommunications network and the local loop, and an entrant, N , which has only the long-distance telecommunications network. Since X has both networks, it can supply an end-to-end service to consumers by itself. On the other hand, N cannot provide an end-to-end service without accessing the local network owned by X . The key question is

how much N should pay X for accessing the network. There are two basic rules that address the access charge problem:

- Incremental cost rule: The access charge should be set based on the average cost that arises as a result of the interconnection of N to the network of X .
- Stand-alone cost rule: The access charge should be set based on the average cost that arises when N produces solely the set of services.

It is said that the incremental cost is the lower limit of the access charge because the new entrant does not pay the common cost between the long-distance network and the local loop at all. On the other hand, the stand-alone cost is the upper limit of the access charge because the new entrant has to pay the total common cost.

As a matter of fact, the above two rules seem to be the extremes; the following intermediate rules are in fact the ones used (Baumol and Sidak, 1994).

- Efficient component pricing rule: The access charge should be equal to the average loss in profit of X that is incurred when it provides access to N .
- Incremental cost plus rule: If the incremental cost rule is adopted, X cannot redeem the past investment; therefore the access charge should be set based on the sum of the average incremental cost and the suitable markup for the redemption.

The efficient component pricing rule is desirable for the bottleneck monopoly in that it obtains the profit irrespective of whether the entry occurs. We cannot insist, however, that this rule is always socially efficient because its profit generally includes monopolistic rents and technical inefficiencies. Accordingly, it is the incremental cost plus rule that is widely supported in many countries¹¹.

Yet, we have not fully analyzed which is socially desirable, behavioral regulation or structural regulation, or whether we can actually control bottleneck monopolies by employing access charges. We will proceed to the model analysis to answer these questions.

3.2 Model analysis of bottleneck monopoly

At this point, we will consider the bottleneck monopoly problem with a model analysis. We define a market in which bottleneck facilities exist as a *one-way connection* and a market in which they do not exist as a *two-way connection*. See Figure 1 for a graphical representation.

¹¹ This is sometimes called the “TELRIC (total element long-run incremental cost)” method, and some economists insist that this rule satisfies allocative efficiencies, technical efficiencies, and dynamic efficiencies (Economides and White 1994, 1995).

<Figure 1 here>

- One-way connection: One firm needs access to another, but the reverse does not hold¹².
- Two-way connection: Customers communicating with each other belong to two different local networks, and each carrier must buy termination access from the other network¹³.

We will compare one-way and two-way connections with a *components model*¹⁴.

The components model analyzes how complementary components are combined to produce a valuable system. We assume that there are two levels of *components*, A and B . It is also assumed that each component has two types, namely A_1/A_2 and B_1/B_2 . One interpretation is that component A denotes a long-distance level, and component B a local loop level in the telecommunications service. We call the combination of components a *system*. In this model, systems are represented by A_1B_1 , A_1B_2 , A_2B_1 , and A_2B_2 . Defining the prices of components A_i and B_j are P_i and Q_j respectively, the price of system A_iB_j , S_{ij} , can be represented as the sum of the prices of components:

¹² See Baumol and Sidak (1994), Laffont and Tirole (1994) for details of the one-way connection model.

¹³ See Laffont and Tirole (2000) for details of the two-way connection model. In the model analysis below, we will extend the definition of the two-way interconnection so that one customer can choose a component of services from multiple companies.

¹⁴ It was Matutes and Regibeau (1988) and Economides (1989) who introduced the components model.

$$S_{ij}=P_i+Q_j; i,j=1,2. \quad (1.1)$$

Let us assume linear demand functions of systems A_iB_j , D_{ij} , following the previous research into components model. The own-effect of price to demand is assumed as one, the cross effects are represented by coefficient c . Accordingly, the demand functions of systems are given as follows:

$$\begin{aligned} D_{11} &= a - S_{11} + c(S_{12} + S_{21} + S_{22}), & D_{12} &= a - S_{12} + c(S_{11} + S_{22} + S_{21}) \\ D_{21} &= a - S_{21} + c(S_{22} + S_{11} + S_{12}), & D_{22} &= a - S_{22} + c(S_{21} + S_{12} + S_{11}). \end{aligned} \quad (1.2)$$

The demand functions of components are given as follows: for example, the demand of component A_1 , D_{A1} , is represented as the sum of the demands of systems A_1B_1 and A_1B_2 , D_{11} and D_{12} :

$$\begin{aligned} D_{A1} &= D_{11} + D_{12}, & D_{A2} &= D_{21} + D_{22} \\ D_{B1} &= D_{11} + D_{21}, & D_{B2} &= D_{12} + D_{22}. \end{aligned} \quad (1.3)$$

In addition, we need further assumptions to simplify the analysis: the non-negative equilibrium prices and quantities, namely $1 > 3c > 0$; the zero marginal costs of production.

- The one-way connection model:

The one-way connection model (abbreviated as $1w$) demonstrates the case where two types of firms exist: one is a dominant firm that monopolizes one level of a component, while the other is a partial entrant. The dominant firm X provides $A_1/B_1/B_2$, whereas the partial entrant N provides only A_2 . Furthermore, X sets the prices of components $A_1/B_1/B_2$, and N sets the price of component A_2 . The firms' profit functions Π_X and Π_N are given as follows:

$$\Pi_X = P_1 D_{A_1} + Q_1 D_{B_1} + Q_2 D_{B_2}, \quad \Pi_N = P_2 D_{A_2}. \quad (1.4)$$

The first-order conditions of the profit maximization problem can be obtained by differentiating profits functions Π_X and Π_N from prices $P_1/Q_1/Q_2$ and P_2 . The equilibrium prices and quantities are shown in Table 1a.

- The two-way connection model:

The two-way connection model (abbreviated as $2w$) demonstrates that there is no dominant firm and that X provides A_1/B_1 while N provides A_2/B_2 . Each component has two types, A_1/A_2 and B_1/B_2 . Component B is compatible with two providers, and B_1 can be combined with A_2 as well as A_1 to produce the systems A_1B_1 and A_2B_1 , respectively. The same can be said of B_2 ; X sets the prices of A_1/B_1 and N sets the prices of A_2/B_2 . The firms' profit functions Π_X and Π_N are given as follows:

$$\Pi_X = P_1 D_{A_1} + Q_1 D_{B_1}, \quad \Pi_N = P_2 D_{A_2} + Q_2 D_{B_2}. \quad (1.5)$$

The first-order conditions of the profit maximization problem can be obtained by differentiating profit functions Π_X and Π_N from prices P_1/Q_1 and Q_2/P_2 . The equilibrium prices and quantities are shown in Table 1b.

The main conclusions obtained from two models can be summarized as the following theorem:

- The first theorem of bottleneck monopoly: $\Sigma D^{1w} < \Sigma D^{2w}$.

This theorem compares the total outputs between the models of one-way and two-way connections, ΣD^{1w} and ΣD^{2w} ¹⁵. Two-way connection is more socially desirable than one-way connection in that the total output of the two-way connection model is larger than that of the one-way connection model. Why is two-way connection more socially desirable than one-way connection? There are two reasons for this. One is the internalization of vertical externalities. Vertical integrators can set prices based upon the demands of systems instead of components. The other is the action of the horizontal substitution effect; since there is no firm that monopolizes components, the price competition in terms of systems works effectively and system demands are increased.

¹⁵ Since prices are higher than marginal costs, outputs are considered socially too low. Accordingly, we can regard the total output of systems as an index indicating social welfare. It is thought that the greater the total output, the higher the social welfare.

From what has been stated, the theorem stated that a bottleneck monopoly is socially inferior to network competition. Next we will examine how to regulate a bottleneck monopoly and improve its performance. There are two possible methods of regulation: access-charge regulation (behavioral regulation) and unbundling (structural regulation).

- Access-charge regulation:

The access-charge model of one-way connection (abbreviated as *1w-ac*) demonstrates what happens when the government regulates the upper limits of prices Q_1/Q_2 of components B_1, B_2 up to f , whereas a dominant firm provides $A_1/B_1/B_2$ and an entrant provides A_2 . X sets the price P_1 and N sets the price P_2 . Profit functions, Π_X and Π_N , are given as follows:

$$\Pi_X = P_1 D_{A_1} + f D_{B_1} + f D_{B_2}, \quad \Pi_N = P_2 D_{A_2}. \quad (1.6)$$

The equilibrium prices and quantities are shown in Table 1c.

- Unbundling:

The unbundling model of one-way connection (abbreviated as *1w-ub*) demonstrates what occurs when the government disintegrates components B_1 and B_2 from a dominant firm X and regulate the prices at level f , while X still provides A_1 and N

provides A_2 . X sets the price P_1 and N sets the price P_2 . Profit functions Π_X and Π_N are given as follows:

$$\Pi_X = P_1 D_{A1}, \quad \Pi_N = P_2 D_{A2}. \quad (1.7)$$

The equilibrium prices and quantities are shown in Table 1d.

<Table 1 here>

The main conclusions obtained from two models can be summarized as the following theorem:

- The second theorem of bottleneck monopoly: $\sum D^{Iw-ac} \geq \sum D^{Iw-ub}$.

This theorem compares the total outputs between the access-charge model and the unbundling model, $\sum D^{Iw-ac}$ and $\sum D^{Iw-ub}$. The former is more socially desirable than the latter in that the total output of the access-charge model is greater than that of the unbundling model. This is because under the access-charge regulation, the dominant firm can determine the price of component A_1 to maximize the total profit of the systems, even though it is not permitted to determine the prices of components B_1 and B_2 . It is interesting to note, in passing, that when the government sets the prices of components B_1 and B_2 to be the marginal costs, namely $f=0$, the equilibrium prices and equilibrium

quantities in the case of access-charge regulation are exactly equivalent to those in the case of unbundling.

3.3 Summary

When we compare the bottleneck monopoly (one-way model), in which one vertically integrated firm monopolizes components at one level, and the network competition (two-way model), in which two vertically integrated firms compete, the latter is socially superior to the former¹⁶. Therefore, we can conclude that a facility-based entry into a bottleneck market is socially desirable, though in reality it will take both money and time for the entrant to construct a substitute network in full. In this sense, we need to regulate the bottleneck monopoly to restrict its significant market power. Next, when we compare behavioral regulation (access charge regulation) and structural regulation (unbundling), we conclude that the former is socially superior to the latter. It is interesting to note that the divestiture of a vertically integrated firm is not necessarily socially desirable.

4. Network externalities

¹⁶ We assume here that each firm can purchase a necessary component to provide an end-to-end service. This means that this industry satisfies the *open access* condition.

This section first previews the characteristics of the demand side of network industries, namely network externalities and second, proposes a model to analyze these problems.

4.1 The preview of network externalities

Network externalities, which represent the economies of scale on the demand side, frequently exist in network industries. For example, a consumer wants to subscribe to a larger network when he/she chooses a mobile phone company, because he/she can talk to more people for the same price. Katz and Shapiro (1994) classified network externalities into two types:

- Direct network externalities: A consumer's utility depends not only on a price but also on a network scale in the communications service. Since the private benefit is lower than the social benefit under network externalities, the scale of the privately owned network tends to be smaller than the socially optimum level.
- Indirect network externalities: Even if the scale of a network does not influence a consumer's subscription choice, the variety of contents will do. An example is *lock-in*, in which hardware that has more usable software is favored by consumers.

Two noteworthy pioneers who have studied network externalities are Leibenstein

(1950) and Rohlfs (1974).

- Bandwagon effect: It is said the external effects of demand exist when one's utility is directly influenced by others' consumption behaviors, either positively or negatively. Leibenstein (1950) in particular called the positive one the *Bandwagon effect*.
- The interdependency of telecommunications demand: The more people consumers can communicate with, the more they are satisfied. The reverse also holds. Rohlfs (1974) analyzed in the telecommunications service that even a potentially viable network might not develop under network externalities because it could not obtain the *critical mass* in the early stage of diffusion.

Many attempts have been made to study network externalities since game theory was widely accepted in the field of Industrial Organization Theory. Most important are studies by Katz and Shapiro (1985) and Farrell and Saloner (1985). First, Katz and Shapiro (1985, 1986a, 1986b) made it clear that the following problems would occur under network externalities:

- Installed base: Network externalities represent the economies of scale on the demand side. If many consumers predict that some network (or technical standard) will spread in the future, they are willing to pay more for it, and it will actually take precedence over others in the manner of a self-fulfilling prophecy.

- Small social incentive of compatibility: It will be problematic under network externalities whether a firm has the proper incentive to interconnect (or make compatibility) with another. The private incentive is expected to be often smaller than the social incentive.

Turning to the next point, Farrell and Saloner (1985, 1986) pointed out that the market mechanism did not necessarily bring about socially desirable welfare.

- Excess inertia: Once an inefficient old technology has already obtained the installed base, another efficient new technology cannot spread.
- Excess momentum: When an inefficient new technology is expected to diffuse in the future, an efficient old technology is driven away from the market.

Typical examples of these market failures are, first, the QWERTY keyboard layout and, second, the standard competition of VCR formats (David, 1985). The original keyboards used in the 19th century often became tangled, so the QWERTY keyboard layout was designed to decrease the speed of typing. Ironically, typewriter performance improved later, and, in addition, the speed of typing needed to be increased. Although the new DVORAK keyboard was invented for this reason, it could not spread because the QWERTY keyboard had already become the *de facto* standard. Moving on to VCRs,

SONY was the first to release the Betamax format in 1975¹⁷. One year later, Victor released the rival VHS format. It was said at that time that Betamax was superior to VHS with respect to picture quality. However, Matsushita and Victor succeeded in establishing strong support for the VHS format by using licensing strategies, and the VHS format finally prevailed.

It is often said that network externalities have played an important role in both of the above cases. For all that, there are some researchers who are cautious in overestimating the importance of network externalities. Representative of this school of thought are Liebowitz and Margolis (2002). They insist that direct network externalities can only apply to very restricted cases such as telephone or FAX services, while many examples of network externalities are in fact indirect, to which the *software-hardware paradigm* applies. Therefore, network externalities do not cause any serious market failures because they are merely pecuniary.

It may be true, as Liebowitz and Margolis have stated, that previous research on network externalities has overemphasized the importance of network externalities. We cannot say for certain at present that government intervention into private activities is always necessary: as long as consumers' or producers' surpluses reflect network externalities even partially, the social welfare will increase regardless. In this respect,

¹⁷ The Betamax format did not satisfy the condition of two-hours' recording time at the beginning, but SONY sold a new version that satisfied this condition the following year.

network externalities are different from public nuisances, which are negative externalities.

4.2 The model analysis of network externalities

Here, we determine whether the network externalities really matter from the perspective of social welfare. An important problem of network externalities is *interlinking*. See Katz and Shapiro (1994), Shapiro and Varian (1998), and Rohlfs (2001) for details. Interlinking is the ability of products to generate network externalities¹⁸. There are two scenarios for this effect. First, the optimistic scenario is that agreeing to interlink is likely to be profitable for all firms if no firm has a strong technological edge, because interlinking yields substantial benefits to consumers and, at the same time, firms can make a profit from the resulting increase in demand. Second, the pessimistic scenario is that the proprietor of a superior technology may be reluctant to interlink, since it stands to win outright when competing with others without interlinking; furthermore, consumers will be reluctant to purchase the product of any competing supplier, as they fear being stuck with a product that may become a losing technology.

¹⁸ Other related concepts are interconnection, compatibility, and technical standards. Interconnection means the ability of users of one network to communicate with users of another network; compatibility means the ability of the base products of all suppliers to work in conjunction with the same complementary products; technical standards means the protocol that defines how the base product works in conjunction with the complementary products.

It appears that the pessimistic scenario, which may feature problems such as a lack of incentives to interlink, or excess inertia/ momentum, has been overemphasized. At this point, upon establishing a simple model of network externalities, we will attempt to determine which scenario is most reasonable; in other words, whether the network externalities truly have the characteristics of market failures.

We consider the Cournot-type duopolistic competition. This competition can be classified into the cases of no interlinking and of interlinking. Furthermore, interlinking falls into two categories: the first is one-way interlinking, where one firm interlinks to the other firm but the reverse does not hold. The second is two-way interlinking, where both firms interlink.

The basic analytical framework is given below, owing much to Katz and Shapiro (1985). In this framework, a consumer purchases one or no unit of a good (in other words, demands access). The surplus that a consumer derives from buying a unit of the good depends on the number of other consumers who join the network interlinked with that good. The term x_i represents the output of the good of firm i , $i=1,2$, and the term y_i^e represents the expected scale of the network that is interlinked with the good of firm i . The term $R + ky_i^e$ corresponds to the willingness of consumers to pay for the good of firm i , where R means that type of consumers that is assumed to be distributed uniformly at a density of one on $(0, A]$; k ($0 < k < 1$) means the parameter that represents

the degree of network externalities. The term P_i means the price of the good of firm i , and the expression $R + ky_i^e - P_i$ describes the net utility function of a consumer who is of type R .

Assuming that the goods are homogeneous except for the expected scale of a network, the equation $P_1 - ky_1^e = P_2 - ky_2^e$ holds. Since R is distributed uniformly on $(0, A]$, the term $A - (P_i - ky_i^e)$ describes the total demand for the goods. The term N denotes the total supply of the goods; then we obtain $N = x_1 + x_2$. Therefore, the equation $A - (P_i - ky_i^e) = N$ represents the equilibrium quantity and the equation $P_i = A + ky_i^e - N$ represents the equilibrium price. Finally, let C_i be the marginal cost of firm i , and we assume here that $C_1 = 0$, $C_2 = c$ ($0 < c < A$). That is to say, firm 1 is superior to firm 2 in terms of costs.

Having assumed Cournot competition, the profit functions, consumer surplus, and social welfare are given as follows:

$$\begin{aligned} \Pi_1 &= x_1(A + ky_1^e - N), & \Pi_2 &= x_2(A + ky_2^e - N), \\ S &= \int_{A-N}^A (R + N - A) dR, & W &= \Pi_1 + \Pi_2 + S. \end{aligned} \quad (2.1)$$

The profit maximization problems of firms 1 and 2 are given as $Max \Pi_1$ and $Max \Pi_2$, and the first-order conditions and equilibrium outputs are given as follows:

$$\begin{aligned} \frac{\Pi_1}{\partial x_1} = A + ky_1^e - 2x_1 - x_2 = 0, \quad \frac{\Pi_2}{\partial x_2} = A + ky_2^e - x_1 - 2x_2 - c = 0 \\ x_1 = \frac{A + 2ky_1^e - ky_2^e + c}{3}, \quad x_2 = \frac{A - ky_1^e + 2ky_2^e - 2c}{3}. \end{aligned} \quad (2.2)$$

Here, Cournot competition is classified into four types, based on the degree of interlinking: (1) no interlinking (*N*), (2) one-way interlinking by a superior firm (*O1*), (3) one-way interlinking by an inferior firm (*O2*), and (4) two-way interlinking (*T*). Furthermore, we will adopt the fulfilled expectations equilibrium (FEE) as an equilibrium concept, following Katz and Shapiro (1985), and consider each maximization problem and equilibrium.

- FEE without interlinking (*N*): Since there is no interlinking, the expected scale of the network of each firm is equal to its output; thus the equations $y_1^e = x_1, y_2^e = x_2$ hold. The FEE (*N*) outputs, profits, surplus, and welfare are given in Table 2a.
- FEE with one-way interlinking by the superior firm (*O1*): Firm 1 is a superior firm in terms of costs. Since there is only one-way interlinking, the expected scale of the network of firm 1 is equal to the total industry output, which is the sum of the outputs of firms 1 and 2; accordingly the equations $y_1^e = x_1 + x_2, y_2^e = x_2$ hold. The FEE (*O1*) outputs, profits, surplus, and welfare are given in Table 2b.

- FEE with one-way interlinking by the inferior firm (*O2*): Firm 2 is an inferior firm in terms of costs. Since there is only one-way interlinking, the expected scale of the network of firm 2 is equal to the total industry output, which is the sum of the outputs of firms 1 and 2; accordingly the equations $y_1^e = x_1, y_2^e = x_1 + x_2$ hold. The FEE (*O2*) outputs, profits, surplus, and welfare are given in Table 2c.
- FEE with two-way interlinking (*T*): Since there is two-way interlinking, the expected scale of the network of each firm is equal to the total industry output, and accordingly the equations $y_1^e = x_1 + x_2, y_2^e = x_1 + x_2$ hold. The FEE (*T*) outputs, profits, surplus, and welfare are given in Table 2d.

<Table 2 here>

Here we compare the social welfare values of the four cases described above. First, because $W^T > W^N$ holds, two-way interlinking (*T*) is more socially desirable than no interlinking (*N*). Second, because $W^T > W^{O1}$ holds, two-way interlinking (*T*) is more socially desirable than one-way interlinking by the superior firm (*O1*). Third, because $W^{O1} > W^{O2}$ holds, one-way interlinking by the superior firm (*O1*) is more socially desirable than that by the inferior firm (*O2*). Fourth, because $W^{O2} > W^N$ holds, one-way interlinking by the inferior firm (*O2*) is more socially desirable than no interlinking (*N*). The above conclusions can be summarized in the following theorem:

- The first theorem of network externalities: Interlinking is better than no interlinking, two-way interlinking is better than one-way interlinking, and one-way interlinking by a superior firm is better than that by an inferior firm.

Next, we determine whether firms want to interlink voluntarily based on non-cooperative game theory. Let us suppose here that players are firms 1 and 2, and strategies are interlinking and no interlinking, then we can obtain the payoff matrix of the game as in Table 3. With the aim of deriving the Nash equilibrium of the game, we solve four inequalities as follows:

$$\begin{aligned}
\Pi_1^T \geq \Pi_1^{O2} &\Leftrightarrow 0 \leq \frac{A}{2-k}, & \Pi_1^{O1} \geq \Pi_1^N &\Leftrightarrow 0 \leq \frac{(1-k)A}{2-k} \\
\Pi_2^T \geq \Pi_2^{O1} &\Leftrightarrow 0 \leq \frac{A}{1-k}, & \Pi_2^{O2} \geq \Pi_2^N &\Leftrightarrow 0 \leq (1-k)A
\end{aligned} \tag{2.3}$$

All inequalities above hold because of $0 < k < 1$. That is to say, a strategy in which firms 1 and 2 interlink becomes the dominant one. Consequently, the Nash equilibrium is two-way interlinking in which both firms want to interlink. In conclusion, we obtain the next theorem:

- The second theorem of network externalities: Both firms have incentives to interlink, and therefore two-way interlinking is realized. In this respect, the market failures in interlinking with network externalities do not happen.

However, this conclusion seems to be too optimistic in comparison to other research¹⁹. In this paper, we have not taken into account the existence of the cost of interlinking (or making compatibility), unlike Katz and Shapiro (1985). If we had included the cost of interlinking in our model, the private incentives to interlink would have been different from the social incentives. We do not mean here that the excess momentum or inertia does not matter; in a sense, we demonstrate under what conditions such market failures actually happen.

4.3 Summary

Network externalities are some of the most important topics in modern economics. As a rule, the negative aspects of network externalities have been overemphasized, though a lot of networking services have voluntarily taken off without special intervention by the government. For that, this paper has demonstrated that network externalities do not always have the characteristics of market failures in interlinking, and a desirable industry structure is likely to be realized as a result of a voluntary interlinking arrangement, based on the simple model of network externalities.

¹⁹ We wish to thank Professor H. Deguchi for directing our attention to this point at the autumn conference 2003 of the Japan Association for Evolutionary Economics.

5. Industrial fusion and the complexity of network economy

In this section, we briefly discuss industrial fusion and the complexity of a network economy.

5.1 Industrial fusion

An interesting topic of network economics is a fusion of industries as a result of innovation and deregulation. Uekusa (2000, p.19) defines industrial fusion as follows:

- **Industrial Fusion:** Industries that had been classified into separate ones have been substituted mutually owing to technical innovations, or firms that were engaged in different businesses have been competing with each other after the deregulation of line-of-business restrictions.

One good example is the fusion of telecommunications and broadcasting. We no longer make a clear distinction between data communication and media broadcasting due to the development of Information Technology (IT) such as opticalization, digitization, interactivation and broadbanding. A similar thing can be said of the energy industries; both electricity producers and city gas have developed cogeneration systems.

Industries that were traditionally considered as being naturally monopolistic are

now becoming competitive after the fusion of industries. However, since economic institutions cannot change as rapidly as technologies, economic regulations that have assumed old industrial structures remain in shackles. In this sense, it is the vested interests of regulated firms and bureaucratic sectionalism that deter the fusion of industries.

Having already demonstrated it in the previous sections, network competition is more socially desirable than bottleneck monopolies, and a fusion of multi-networks is socially preferable. Therefore, the industrial policy of the future is not only to control market power and open essential facilities inside an industry, but also to promote mutual entries into highly centralized markets and establish rules for equal footing.

5.2 The complexity of a network economy

As has been emphasized above, the two main points of network economics are bottleneck monopolies, which are economies of scale on the supply side, and network externalities, which are the economies of scale on the demand side. At this point, we collectively refer to them as *the economies of network*.

- The economies of network: Bottleneck monopolies originate in the economies of scale, which cause an irreversible entry-and-exit due to enormous sunk costs, bringing an incumbent firm huge vested interests. On the other hand, network

externalities also make the choice of a consumer irreversible owing to switching costs.

It is important here to understand that the network economy is not founded in “simplicity,” but in “complexity” (Arthur, 1989).

- The complexity of a network economy: It is impossible to predict which firm will be able to appropriate the economies of network because a *path dependency* can occur, depending on the initial condition. Also, since positive feedback is caused by the economies of network, *lock-in* occurs and excess inertia or momentum matters. Consequently, the complex network economy is very different from the simple world that standard economics, like the general equilibrium theory, has presumed.

The purposes of network economics are to understand complex phenomena such as the growth and atrophy of firms, the emergence of innovation, the life cycle of commodities, the transition of consumers’ preferences, and the development of industry (Antonelli, 1997). Thus, network economics is also a form of evolutionary economics.

6. Conclusion

This paper has discussed several aspects of network industries that are important in the modern economy. There are two main points in network industries: bottleneck monopolies and network externalities. Both represent the economies of scale on the supply and demand sides, and therefore the market mechanism may not work well. Furthermore, network industries have been merging, and the complexity surrounding the network economy has been increasing. Consequently, it is impossible to accurately predict the result of industrial policy, although it will be possible to design a higher grade of industrial policy under the assumption that we are not able to predict the future.

As a final point, we have to mention future subjects to be dealt with. While we have stated that network economics should be evolutionary, the models that we have analyzed are still static, based on the standard equilibrium theory. We wish to break through these technical difficulties and develop an evolutionary model for investigating developing network industries.

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Fig. 1: One-way and Two-way connections

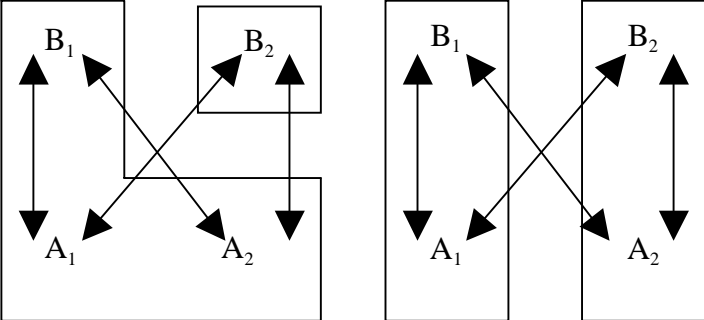


Table 1: Demands and outputs of each system

(a) Bottleneck monopoly (1w)

D_{11}^{1w}	D_{12}^{1w}	D_{21}^{1w}	D_{22}^{1w}	ΣD^{1w}
$\frac{a(3-c)}{6(1-c)}$	$\frac{a(3-c)}{6(1-c)}$	$\frac{a}{3}$	$\frac{a}{3}$	$\frac{a(5-3c)}{3(1-c)}$

(b) Network competition (2w)

D_{11}^{2w}	D_{12}^{2w}	D_{21}^{2w}	D_{22}^{2w}	ΣD^{2w}
$\frac{a(3-5c)}{7-17c}$	$\frac{a(3-5c)}{7-17c}$	$\frac{a(3-5c)}{7-17c}$	$\frac{a(3-5c)}{7-17c}$	$\frac{4a(3-5c)}{7-17c}$

(c) Access charge regulation (1w-pc)

D_{11}^{1w-pc}	D_{12}^{1w-pc}	D_{21}^{1w-pc}	D_{22}^{1w-pc}	ΣD^{1w-pc}
$\frac{a(1-c) + c(-1+2c+3c^2)f}{2-4c}$	$\frac{a(1-c) + c(-1+2c+3c^2)f}{2-4c}$	$\frac{(1-c)(a + (-1+2c+3c^2)f)}{2-4c}$	$\frac{(1-c)(a + (-1+2c+3c^2)f)}{2-4c}$	$\frac{2a(1-c) + (-1+2c+3c^2)f}{1-2c}$

(d) Unbundling (1w-ub)

D_{11}^{1w-ub}	D_{12}^{1w-ub}	D_{21}^{1w-ub}	D_{22}^{1w-ub}	ΣD^{1w-ub}
$\frac{(1-c)(a + (-1+3c)f)}{2-4c}$	$\frac{(1-c)(a + (-1+3c)f)}{2-4c}$	$\frac{(1-c)(a + (-1+3c)f)}{2-4c}$	$\frac{(1-c)(a + (-1+3c)f)}{2-4c}$	$\frac{2(1-c)(a + (-1+3c)f)}{1-2c}$

Table 2: The FEE equilibrium, profit, surplus, and welfare

(a) No interlinking (N)

x_1^N	x_2^N	Π_1^N	Π_2^N	S^N	W^N
$\frac{(1-k)A+c}{(1-k)(3-k)}$	$\frac{(1-k)A-(2-k)c}{(1-k)(3-k)}$	$(x_1^N)^2$	$(x_2^N)^2$	$\frac{(x_1^N+x_2^N)^2}{2}$	$\frac{3(x_1^N+x_2^N)^2-4x_1^Nx_2^N}{2}$

(b) One-way interlinking of firm 1 (O1)

x_1^{O1}	x_2^{O1}	Π_1^{O1}	Π_2^{O1}	S^{O1}	W^{O1}
$\frac{A+(1-k)c}{k^2-3k+3}$	$\frac{(1-k)A-(2-k)c}{k^2-3k+3}$	$(x_1^{O1})^2$	$(x_2^{O1})^2$	$\frac{(x_1^{O1}+x_2^{O1})^2}{2}$	$\frac{3(x_1^{O1}+x_2^{O1})^2-4x_1^{O1}x_2^{O1}}{2}$

(c) One-way interlinking of firm 2 (O2)

x_1^{O2}	x_2^{O2}	Π_1^{O2}	Π_2^{O2}	S^{O2}	W^{O2}
$\frac{(1-k)A+c}{k^2-3k+3}$	$\frac{A-(2-k)c}{k^2-3k+3}$	$(x_1^{O2})^2$	$(x_2^{O2})^2$	$\frac{(x_1^{O2}+x_2^{O2})^2}{2}$	$\frac{3(x_1^{O2}+x_2^{O2})^2-4x_1^{O2}x_2^{O2}}{2}$

(d) Two-way interlinking (T)

x_1^T	x_2^T	Π_1^T	Π_2^T	S^T	W^T
$\frac{A+(1-k)c}{3-2k}$	$\frac{A-(2-k)c}{3-2k}$	$(x_1^T)^2$	$(x_2^T)^2$	$\frac{(x_1^T+x_2^T)^2}{2}$	$\frac{3(x_1^T+x_2^T)^2-4x_1^Tx_2^T}{2}$

Table 3: The incentive of interlinking

		Firm 2	
		Interlinking	No interlinking
Firm 1	Interlinking	Π_1^T, Π_2^T	Π_1^{O1}, Π_2^{O1}
	No interlinking	Π_1^{O2}, Π_2^{O2}	Π_1^N, Π_2^N