Models of Interconnection in Telecommunications

Sang Taek Kim and Hyeong-Chan Kim [1]

We proposed and utilized a simple model to review relay interconnection literatures. Without any complications of scale economies and opportunity costs, marginal cost pricing of interconnection charge is optimal. When incumbent sets the interconnection charge, it may or may not foreclose entrants depending upon degree of entrant's efficiency and forms of interconnection charge. When there are opportunity costs for incumbent to interconnect, then opportunity cost should be paid by the entrant according to the efficient component pricing rule. When there are economies of scale, Ramsey pricing comes to rescue. In an extension of Ramsey spirit, the global price caps are suggested.

Next, we have reviewed the current status of the two-way access theory. First, a case of collusive retail prices has been presented even when the market competition exists between symmetric networks. In this case, the use of two-part tariffs or price discrimination can help, as they enable firms to compete in market shares without affecting their access payments. Various types of Internet interconnection are presented along with main results by Laffont, Marcus, Rey and Tirole (2001a, b) on the pricing issues of Internet interconnection.

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*Assistant Professor, Department of Economics, Ewha Womans University, 11-1, Daehyun-Dong, Sudaemun-Ku, Seoul 120-750, Korea, (Tel) +82-2-3277-2772, (E-mail) sangkim@ewha.ac.kr; Senior Research Fellow, KISDI, 1-1, Jooam-Dong, Kwachun-si, Kyunggi-Do 427-070, Korea, (Tel) +82-2-570-4260, (E-mail) hckim@kisdi.re.kr, respectively. We are grateful to Dr. Youngsub Chun and Participants at International Symposium on Cost Allocation in Telecommunications sponsored by Institute of Economic Research of Seoul National University and Korea Information Society Development Institute. We are also grateful to Dr. Jongwha Lee of KISDI for valuable comments. We also wish to acknowledge the financial support of internal research funds from Ewha Womans University. This article reflects the views of the authors.

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I. Introduction

Telecommunications industry is a network industry. It is also technologically progressing rapidly. Characteristics of network industries are two-fold. First, it shows economies of scale. It may come from the existence of fixed cost or from the technology itself. A large amount of fixed cost is required just to maintain a network in telecommunications industry. Existence of fixed cost ensures economies of scale. It is also well-known that network industry exhibits increasing returns to scale. For example, area of the pipeline quadruples while pipeline's circumference doubles. The second characteristic is network externality. Because of network externality, consumers and operators of network services can benefit from networks' interconnection.

Interconnection is also central to the development of an effective telecommunications industry. The old monopoly model is in the process of disappearance. The single operator is considered inefficient to provide telecommunications services. Competition has been introduced in the industry. The interconnection between operators is a prerequisite for the introduction of competition, since otherwise it is very difficult, if not impossible, for new entrants to survive in the industry with incumbents enjoying economies of scale and network externality.

This paper surveys models of interconnection in telecommunications. These models can be categorized into two different types of interconnection. The first is relay interconnection, while the second is interconnection between two independent networks. By independent networks, we mean networks with subscribers within which calls can be originated and terminated. Interconnection between independent networks is also called two way access. Examples of this type of interconnection are between two mobile networks, and between fixed network and mobile network.

A good example of relay interconnection is long distance services. For illustrative purposes we depicted in diagram 1-1 long distance competition based on interconnection with local exchange bottleneck. A telephone operator, the incumbent, controls the local bottleneck and faces competition by one or several competitors, the entrants, in the long distance market. Entrants need interconnection with the local network in order to reach end users. Entrants

Local Bottleneck	Long Distance Services
Incumbent	Incumbent
	Entrant

[Diagram 1-1]

pay interconnection charge to the incumbent. Interconnection charge is a cost to the entrant, while it is an income to the incumbent. Therefore, interconnection charge plays an important role in competition. If interconnection charge is too high, then entrants will lose competitive edge. If it is too low, incumbent will become less competitive.

We will survey the relay interconnection first. In section III, we will go over the interconnection between independent networks. In section IV, interconnection in Korean telecommunications industry will be presented along with key issues and possible policy suggestions for Korea. We conclude in section V.

II. Relay Interconnection

A. Simple Model

Two stage decision-making processes are considered to explain the way that interconnection charge affects the long distance market. In the market, there are two firms, incumbent and a new entrant.[1] Incumbent owns and operates local bottleneck services along with long distance services. Entrant does not own local bottleneck, but it owns and operates long distance networks. Thus it needs interconnection with the local bottleneck to reach end users.

At the first stage, interconnection charges are determined. One needs to know the objectives of interconnection charge in order to determine the level of interconnection charge. However, objectives of interconnection charges change depending upon who decides the

[1]The entrant is assumed to be in the market. The decision for an entrant whether to enter the market or not will be considered in the process of analysis later.

Local Bottleneck	Long Distance Services
Incumbent's Cost c_b	c_i
Entrant's Cost a	c_e

[Diagram 2-1]

level of interconnection charge. Decision maker can be either the incumbent operator or a social planner or joint committee of the incumbent and entrant. The social planer decides the interconnection charges to maximize social welfare. Incumbent decides it to maximize incumbent's profit, while in other case to maximize joint profit for interconnected firms.

At the second stage, firms are assumed to produce a homogeneous service and compete with prices to maximize its own profit in Bertrand fashion. That is, the operator who offers lower price captures the whole long distance market. Market will be split in half when two prices offered by operators are the same. A new entrant will pay interconnection charge a to the incumbent. Hence, the entrant will incur its own marginal cost c_e and interconnection charge a to provide long distance service to its customer. Incumbent will incur marginal cost c_i for its long distance service, while its local bottleneck will incur another marginal cost c_b to produce one unit of output. For now, there is no fixed cost. For simplicity, local bottleneck services cannot be sold directly to end-users.

B. Foreclosure and Marginal Cost Pricing

Many people believed that incumbent monopolist simply did not want competition. Thus foreclosure is inevitable. The simple way of foreclosure is refusal to interconnect with any possible entrant. This story has been widespread among many people. However, it is shown that this story may or may not be true. If an entrant is much more efficient than incumbent's downstream, then incumbent will not foreclose the entrant. In other cases, the story may be true. We will explain this in more detail.

Let's solve the game stated above. This two-stage game can be solved by the method of backward induction. We first remind readers of the Bertrand result that two firms will end up with the price equal to marginal cost when their marginal costs are the same. Market share of each firm will be half. When their marginal costs are different, the firm with the lower marginal cost will capture the whole market with the price slightly less than the opponent's marginal cost.

Let's consider the second stage first as backward induction suggest. At the second stage of a given fixed interconnection charge, entrant's total marginal cost to provide one unit of services will be $(a+c_e)$. Incumbent's total marginal cost is (c_b+c_i). Therefore incumbent will set the price slightly less than $(a+c_e)$ and capture the whole market as long as $(c_b+c_i)<(a+c_e)$. If $(c_b+c_i)>(a+c_e)$ is true, then entrant will set the price slightly less than (c_b+c_i) to grab the whole market. When marginal costs of two firms match, then two firms will share the market in half. For this simple case, the firm with lower marginal cost (or with more efficient technology) will capture the market. However, interconnection charge affects the entrant's marginal cost, which determines the competitiveness and efficiency of the market. Hence, interconnection is very important for competition.

Suppose two firms are equally efficient producers of the services. In other words, $c_e=c_i$. Also suppose that the interconnection charge a is determined to maximize the incumbent's profit. What would be the level of interconnection charge? There are two cases.[2] The first is the case that entrant's marginal cost is equal to or higher than the incumbent's marginal cost of long distance division. In this case, incumbent can and will set the interconnection charge so high that entrant's market share becomes zero. In other words, incumbent will foreclose the less efficient entrants.

The second is the case that entrant is more efficient than the incumbent in the long distance market. In this case, incumbent chooses one of two alternatives depending upon the form of interconnection charge. Suppose interconnection charge is non-linear and entrants are price-takers in the interconnection market.

[2]Of course, non-linear tariff is a good candidate to consider. However, we will not consider that possibility for now. Instead we will focus on linear tariff case.

Incumbent can set the interconnection charge such that entrant enjoys only minimal profit, while incumbent enjoys the maximal profit extractable from the entrant. In this case, incumbent's profit will increase compared to the level of profit before the entrance of the competitor.

Interconnection charge should consist of subscription part and usage part. Subscription part should be independent of the quantity of services bought by the entrant, but it should be set slightly less than the entrant's potential profit. Usage part of interconnection charge should be set equal to the marginal cost of bottleneck service provision. As a result of this non-linear interconnection charge, efficient entrant will stay in the business to attain minimal profit allowed by incumbent. Entrant's action will also be in line with the incumbent's incentive to maximize profit. Since incumbent will enjoy even higher profit than before the introduction of competition, it will not foreclose efficient entrants.

In case of linear interconnection charge, there are two possibilities. The first case is double marginalization. Incumbent sets interconnection charge high to maximize its own profit and entrant still adds another margin on the final services. The resulting final price will be even higher than the single monopolist case. Therefore industry profit will decrease compared to the ideal case of the monopolist. In this case of double marginalization, incumbent's profit may decrease if incumbent allows an efficient entrant to compete. Hence, incumbent will set interconnection charge so high that entrant cannot compete in the market. The second case of linear interconnection charge is that entrant is much more efficient than the first case. So incumbent's profit becomes larger than the one in foreclosure case even after considering double marginalization. In this case, incumbent would not foreclose an efficient entrant. Rather it will allow competition and enjoys higher profit than before.

What would happen if a social planner determines the interconnection charge to maximize social welfare? It is well-known that marginal cost pricing is the most efficient pricing practice at the "normal" situation.[3] Besides marginal cost pricing for the inter connection charge is necessary to prevent foreclosure mentioned

[3]By the "normal" situation, we mean the situation with no externality, no information problem, no economies of scale and so on.

	Local Bottleneck	Long Distance Services
Incumbent's Cost	$c_b + c_o$	c_i
Entrant's Cost	a	c_e

[Diagram 2-2]

above. In other words, as long as interconnection charge a is not equal to the marginal cost c_i, there is room for vertical foreclosure. If $a > c_b$, then incumbent can foreclose the equally efficient entrant (that is, $c_i = c_e$). Likewise, if $a < c_b$, entrant can foreclose equally efficient incumbent's long distance division. Therefore interconnection charge should be equal to the marginal cost of incumbent's local exchange bottleneck. The traditional pricing principle of economics is reconfirmed.

C. Efficient Component Pricing Rule

Suppose that incumbent also incurs additional opportunity cost c_o of providing interconnection services to new entrants. Incumbent's cost to provide interconnection service is marginal cost (c_b) of interconnection service and opportunity cost (c_o). Entrant's total cost is ($a + c_e$), while incumbent's total cost is ($c_b + c_o + c_i$). Since local bottlenecks are used and shared by both firms, one should compare costs of two firms in the long distance market if one wants to compare efficiency of two firms. In other words, c_i and c_e should be compared to decide which firm is more efficient. However, entrant competes in the market with total cost ($a + c_e$), while incumbent competes with total cost ($c_b + c_o + c_i$). To ensure fair competition, interconnection charge a must be equal to ($c_b + c_o$). If so, two firms compete on a level playing field with costs of the long distance service provision. This rule to set interconnection charge such as $a = (c_b + c_o)$ is called efficient component pricing rule. Sometimes it is called, "Baumol-Willig rule" or "Parity-pricing formula."

Baumol (1983), Willig (1979) and Baumol and Sidak (1994) claim that an entrant should compensate incumbent not only for marginal cost, but also for the opportunity cost. Otherwise a new entrant has an unfair advantage over incumbent since incumbent has to suffer additional opportunity cost caused by the entrant. Let's explain this from a different point of view. If $a=(c_b+c_o)$ is true, an entrant can enter the market only when c_b is less than or equal to c_i. In other words, entrant enters the market only when it is more efficient than incumbent. Otherwise entrants will suffer loss, since incumbent will set the price slightly less than entrant's marginal cost $(c_b+c_o+c_e)$ to take the whole market. Eventually entrant will go out of business. This is called productive efficiency. It is the major benefit of ECPR claimed by Baumol and Sidak (1994) that inefficient firms can't enter the market.

We assumed above that opportunity cost was a variable cost. What if opportunity cost is a fixed cost? If linear interconnection charge per usage reflects the fixed cost as well as variable cost, entrant's optimal demand for interconnection services will change. The result is inefficient service provision by the entrant from the society's point of view. One way to solve this problem is the two-part tariff system of interconnection charge. While marginal interconnection charge is set equal to the marginal cost of interconnection service provision, amount of the fixed cost should also be paid in lump sum manner to incumbent as part of interconnection charge. In this way, entrant's incentives do not get distorted. At the same time incumbent's profit is not less than zero. Thus strength of ECPR still holds for the fixed opportunity cost, if two-part tariff system of interconnection charge is applied.

D. Ramsey Pricing

The marginal cost pricing principle is efficient when there are no economies of scale. If economies of scale exist, marginal cost pricing of interconnection charge leads to negative profit for the incumbent. If this case persists, incumbent will go out of business. If so, new entrant also goes out of business without the local bottleneck services. Therefore, for incumbent to have no less than zero profit, either incumbent or entrant (or both) have to pay higher interconnection charge than marginal cost of local bottleneck service provision.

The problem is to maximize an objective[4] with the IR (Individual Rationality) condition that incumbent's profit is not less than zero.

The answer to this optimization problem is the well-known Ramsey principles of inverse elasticity. That is, more inelastic supplier of long distance services should pay higher interconnection charge than elastic supplier pays. Therefore entrant should pay high interconnection charge[5] if it exhibits highly inelastic demand. These Ramsey principles of interconnection are confirmed by Armstrong, Doyle and Vickers (1996) and Laffont and Tirole (1994).[6]

E. ECPR and Ramsey Pricing

ECPR solves the problem of negative profit caused by opportunity cost. Ramsey principles solve the problem of negative profit caused by economies of scale. Both of these two rules solve the problem of negative profits, though the deficits came from the different causes. Since they solve the same type of problem, they must have some relationship. Laffont and Tirole (1994) formalizes this intuition with a differentiated product model instead of homogeneous products assumed in ECPR. They show that interconnection charge based on ECPR is equal to the one based on Ramsey principles when demand and cost are symmetric between incumbent and entrant.

F. Critics and Modifications of ECPR

Armstrong, Doyle and Vickers (1996) had shown that ECPR should be modified in a number of circumstances. The complications that require this modification are creation of new market so that incumbent loses fewer consumers than entrant's new consumers. In other words, total consumers increase as entrant enters the market. The second is the case that imperfect substitutes for the services of local bottleneck are available. The third is the case that services provided by entrant are differentiated from incumbent's services. In other words, two services are not perfect substitutes. In these cases, they claim that opportunity cost in ECPR should in general be lowered by an "adjustment factor."

[4]Objectives can be social welfare or incumbent's profit or joint profit *etc.*

[5]However, interconnection charge is still higher than the marginal cost as long as fixed exists.

[6]Laffont and Tirole (1994) assume that entrant provides less than perfect substitute services. Armstrong, Doyle and Vickers (1996) assume both cases of differentiated products and homogeneous product. In both papers, Ramsey principles are confirmed.

The adjustment factor reflects and measures the degree of market creation, bypass possibility and product differentiation. Kim and Lee (1997) also points out that opportunity cost calculation of ECPR should be modified to reflect economies of scope between local bottleneck and final service provision only when they exist under the management of one firm.

Economides and White (1995, 1996) provide additional criticism that the opportunity cost component of ECPR can contain a monopoly markup, and that there is no justification for preservation of such monopoly markup through the imposition of ECPR. In this case of monopoly pricing, welfare may improve if interconnection charge is lower than what ECPR suggest. The welfare gain comes from the lower consumer price induced by "inefficient" competition. Baumol, Ordover and Willig (1997) comments on this criticism that ECPR should be applied after the adjustment of retail price.

G. Global Price Cap

Laffont and Tirole (1996) demonstrates that a regulator can provide incumbent proper incentives for efficiency in the allocation of the bottleneck services and long distance services through the imposition of "global price caps." Under global price caps, incumbent is constrained not only in the prices of final products, but in the prices of bottleneck services as well. A weighted average of all these prices should not exceed an appropriately selected number. Weights used in the computation of the price caps should be exogenously determined and should be proportional to the forecasted demands. If so, the global price caps are claimed to lead automatically the incumbent to meet the requirement of efficiency in the allocation of the bottleneck services and long distance services.

Intuition behind this claim is that incumbent should balance between two services based on the weighted price cap. Suppose incumbent puts more weight on the interconnection, so that it set interconnection very high and price very low. Then efficient entrant will not provide as much service as before. Income from interconnection charge decreases. However, inefficient Technology of incumbent would be utilized more to supply reduced service of entrant. Income from incumbent's service provision increases. The total result will be loss to incumbent. That is, there is an optimum level of price and interconnection charge. However, according to Baumol, Ordover and Willig (1997), there exists a difficulty of forecasting proper weights and demands. If the final demands and weights are not properly forecasted and chosen, the requirement of efficiency will not be satisfied in the allocation of the bottleneck services and long distance services. If price caps are too high or too low than the desired level, incumbent can either have room for predation of entrant or have no room for its own survival. Baumol, Ordover and Willig (1997) go on to claim that ECPR can supplement global price caps in this regard.

III. Two-Way Access

A. Introduction

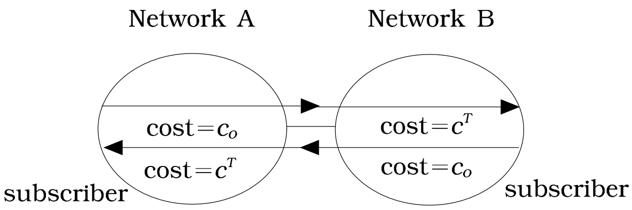
The two-way access is required when a customer of one network needs to communicate with customers of the other network, and vice versa. Examples of two-way access include interconnection between:

- Two local exchange carriers,
- Two mobile telephony operators,
- A local exchange carrier and a mobile operator, or
- Two carriers of different countries (to provide the international telephony service).[7]

In all of the above, each network buys the termination service from the other network to provide some end-to-end, off-net voice telephony services. A customer then pays his/her network for these end-to-end services. A simple two-way access situation is depicted in Diagram 3-1.

In each of the first two examples above, a carrier can provide the service in question (*i. e.*, the local call in the first example and the mobile telephony in the second) individually. Therefore, the main need for the two-way interconnection arises from the possibility of

[7]Interconnection involving data networks, notably Internet, requires separate discussion due to economic and regulatory distinctions. We discuss Internet interconnection in Subsection C.



[Diagram 3-1] Two-Way Access

providing communications services with a larger group of people. The interconnection may increase the value of both networks from the network externality (although a smaller network may benefit more than a larger one). It also enables the firms to provide comprehensive (on-net and off-net) services, thereby providing more revenue sources. However, at the same time, two networks compete for the same retail service market. Also, an originating network of an on-net call has to pay some fee (access charge) for the termination.

Assume that the interconnection is given.[8] The conflicting incentives above give rise to the following important questions for the determination of the access charges: First, will the carriers reach an agreement through the commercial negotiation, and if so, is the agreement efficient? Second, if the regulation is needed to ensure socially efficient outcomes, how should the regulator intervene?

Subsection *B* of this section of the paper aims to survey the theoretical contribution to answer these questions. Only a limited number of theoretical analyses have been made in this area. However, they have made some important contributions to the understanding of the nature of the issues and basic policy directions. One may argue that, once market competition develops, the sector-specific regulations should be replaced by standard competition policy.[9] However, the current literature seems to suggest that, in some cases, a regulatory intervention may be

[8]All of the models we surveyed make this assumption. We think this assumption may be valid given the current market situations and the regulatory arrangements.

[9]See Laffont and Tirole (2000, p. 8).

necessary even when equal-sized carriers are 'competing' in the market and they reach a commercial agreement. More specifically, when demand and cost faced by the networks are symmetric, if two competing services are sufficiently differentiated, the carriers may use the access charge as an instrument of collusion in the retail services market. We present the major contributions made by Armstrong (1998) and Laffont, Rey and Tirole (1998).

The third example of two-way access presented above is similar to the first and the second in that the carriers compete, to some degree, in the voice telephony market. Therefore, the same questions we posed also apply here. However, there may be also distinguishing features since the services of the two carriers are quite different in functionalities and cost structure. Wang, Yoon and Jeon (1999) argue that a land service and a mobile service could be complementary (as a customer can subscribe to both networks – a possibility not analyzed by the three papers in the last paragraph) as well as substitutable. Also, because of the difference in the cost structure, 'the reciprocity of access charges' [10] may not be a relevant assumption.

The last example of two-way access presented above is quite different in nature from the other three examples. Interconnection is required by two carriers of different countries to provide a service that an individual carrier cannot provide on its own, namely, the international telephony service. A more fundamental distinction from the theoretical perspective is that the carriers are not competing for the same market. To focus on the issues arising from the network competition, we do not cover the 'international settlement' issue in this paper. Interested readers are refered to, for example, Yun, Choi and Ahn (1997).

In the subsection *C*, we discuss the characteristics of, and possible issues for the Internet interconnection. We begin by identifying different types of interconnection that can arise between Internet networks. Some of these are similar in nature to the interconnection between telephone networks. However, authors in this field emphasize the need for separate theoretical treatments. We

[10] This means that the access charge, paid by one network for a unit of call made to the other network, is the same for both networks. Armstrong (1998) and Laffont, Rey and Tirole (1998) employ this assumption. Economides, Lopomo and Woroch (1996) study the effects of imposing the reciprocity rule.

summarize some of the economic and regulatory distinctions between Internet services and telephone services. Also, we briefly introduce the main results of Laffont, Rey, Marcus and Tirole (2001 a, b) on the pricing issues of Internet interconnection.

B. Contributions to the Theory of Two-Way Access

a) Symmetric and Unregulated Industry

We begin by explaining the first major conclusion of Armstrong (1998) and Laffont, Rey and Tirole (1998), *i. e.*, why and how the access charge may be used as an instrument of collusion in the retail services market in a symmetric and unregulated industry.[11] Both articles study the analogous analytical model to draw this conclusion. They consider a Hotelling model of consumer choice in which two networks, A and B, are located at 0 and 1, respectively, of the unit interval [0,1].[12] Consumers are assumed to be uniformly located on that interval.

A consumer of type x gains utility of $u_A+\alpha(1-x)$ and $u_B+\alpha x$ by joining the network A and B, respectively, where u_i is the utility from using the network i=A, B and α is the 'transportation cost' parameter so that a low value of α represents the high substitutability. Then the market share of A would be

$$s(u_A-u_B)=1/2+(u_A-u_B)/2\alpha,$$

if $|u_A-u_B|\leq\alpha$. Otherwise, one of the firms will corner the market. Assume that there is no *call externality*, that is, consumers receive utility only from making the calls but not from receiving them. A subscriber's demand does not depend on the retail price of the other network. Two networks face the same demand function. Considering linear retail prices, u_i can be written by $u_i=v(p_i)$. Here, $v(p)$ is the consumer surplus, $v'(p)\equiv-q(p)$ and p_i is the retail price of i=A,B which is assumed, for the moment, to be not discriminated between on-net and off-net calls. The fundamental

[11]Both Armstrong (1998) and Laffont, Rey and Tirole (1998) call this situation the "mature" phase of industry, which may correspond to the current status of competition in the mobile telephony. Meanwhile, an asymmetric and regulated case is termed the 'early' (Armstrong 1998) or 'transition' phase (Laffont, Rey and Tirole 1998).

[12]In this subsection, we follow the model specification of Armstrong (1998).

assumptions both Armstrong (1998) and Laffont, Rey and Tirole (1998) employ are the following:

- Balanced calling pattern: The fraction of calls originating in each network and terminated by one network equals to the market share (in terms of the number of subscribers) of the latter network.
- Reciprocity of access charges: The same per-unit access fee is charged by each network for terminating the rival network's off-net calls.

The first assumption simplifies the analysis and designates a straightforward relationship between the market shares and the access deficit. Specifically, the net number of calls from B to A can be written by

$$z(p_A,\ p_B) \equiv s(1-s)[q(p_B)-q(p_A)].$$

From this, it can be seen that the network charging a lower retail price would incur a net outflow of calls. Therefore, a firm that slightly undercuts the other would increase its market share but also incur an access deficit (given some moderate value of α). These conflicting effects are one of the foundations of the main result of the models.

Assume that, in this symmetric case, each network incurs the cost, c^0, of originating a call that terminates at the rival's network and the cost, c^T, of terminating the rival's off-net call (see again Diagram 3-1). The cost of on-net call is assumed to be c^0+c^T. Also, assume that the fixed cost of connecting a subscriber is given by c^F. Then, the common per-user profit for a network from the retail sector is

$$\pi(p) \equiv q(p)(p-c^0-c^T)-c^F. \tag{1}$$

Using the assumption of the reciprocity of the access charge, denoted by t, the total profits for the networks are given by

$$\Pi_A = s\pi(p_A)+z(t-c^T) \text{ and } \Pi_B = (1-s)\pi(p_B)-z(t-c^T). \tag{2}$$

Consider the following order of events. First, the access charge, t, is chosen by the networks. Second, the networks choose their retail prices non-cooperatively (and the consumers make the subscription decision). We begin by considering the second stage. Assuming the symmetric demand, so that $s(u_A-u_B)\equiv 1-s(u_B-u_A)$, and rearranging the first order condition to maximize Π_A of (2), we see that

$$t=c^T+[-\partial(s\pi)/\partial p_A]/[\partial z/\partial p_A] \tag{3}$$

where $p_A=p_B=p$.

Assume that the networks collude under reciprocity and agree on an access charge in the first stage.[13] Then, they would choose $t=t*$ that can sustain a retail price, $p*$, that maximizes their joint profit, $s\pi(p_A)+(1\text{-}s)\pi(p_B)$. It is easy to see that $p*$ is the price that maximizes the individual profit, $\pi(p)$, since $0\leq s\leq 1$. Thus, $\pi'(p*)=0$ if $\pi(p)$ is single-peaked. Consider an access charge $t*$ which is given by setting $p=p*$ in (3):

$$t*=c^T+[-4s'(0)q(p*)/q'(p*)]\,\pi(p*) \tag{4}$$

where $s(0)=1/2$ by symmetry. The second term of the right-hand side of (4) is positive since $s'(0)$ is positive. Therefore, $t*$ would be higher than the marginal cost, *i.e.*, $t*>c^T$.

If the access charge is set at $t=t*$, when a network undercuts the other, the increase in its profit from the increased market share would be exactly offset by the increase in access payment. Therefore, the networks do not have incentives to deviate from $p*$. It remains to be seen whether $p*$ actually is an optimal response of one network when the other sets $p=p*$. Suppose that the networks are highly substitutable so that there is an intense retail price competition. Then, if a network undercuts slightly, it might be able to corner the market at a price close to $p*$. The undercutting firm would not have to pay for the access at all, so that a collusive price $p*$ cannot be sustained as an equilibrium.[14] On the other

[13]Amstrong (1998) notes that the networks will set a higher charge when they act non-cooperatively than when cooperatively, a case also made by Laffont, Rey and Tirole (1998). This is due to the ‘double marginalisation’ problem. Readers are also referred to Economides, Lopomo and Woroch (1996) for the effects of imposing the reciprocity.

[14]See the interpretations in Laffont and Tirole (2000, pp. 190-8).

hand, if the substitutability is not very high, a large price-cut would be needed to obtain this effect but there may be no price that makes such strategy profitable. This is why the existence of a symmetric equilibrium depends on the substitutability between the competing networks.

Note also that if the access charge *were* set close to the marginal cost, then the average marginal cost of (on-net and off-net) calls would roughly be independent to the increase in market share. Then, $p*$ would be sustained as an equilibrium also for a high substitutability, as one network does not gain from undercutting its retail price (Proposition 1 (i) of Laffont, Rey and Tirole (1998)).

This result may suggest that the regulation be needed even in a market where two symmetric networks compete. When the networks are sufficiently differentiated, a high access charge may be used as an instrument of collusion in the retail market, as it makes price-cuts very costly by increasing the access payment. This basic result depends on the assumptions made by Armstrong (1998) and Laffont, Rey and Tirole (1998). Before discussing their own extensions, we point out that considering a more general calling pattern than a balanced one of their models may provide a useful area of future researches. For example, one can assume that consumers are heterogeneous in their preferences for the on-net and off-net calls.

Next, we turn to the second question posed in the introductory subsection, namely, how should the regulator intervene and explore the socially efficient access charge. Clearly, the welfare-maximizing retail price, $p**$, would be given by setting $\pi(p**)=0$. This implies that, from (3), the welfare-maximizing access charge is given by the following.

$$t**=c^T+2\pi'/q'(p**)$$

It is lower than the marginal cost c^T.[15] The intuition is that when the networks are differentiated, they enjoy some market power and a price/cost markup would exist in the retail price. Access service is subsidized in order to offset the mark-up.

[15]Of course, for imposing $t=t**$ to be an effective regulatory measure, $p=p**$ should be sustained as an equilibrium strategy if the retail sector is left unregulated.

Finally, both models discuss the relationship between the access charge given by (3) and ECPR. That is, (3) is just an interpretation of ECPR in a symmetric and unregulated case, since the first term of the right-hand side is the terminating marginal cost and the second term is the loss of A's retail profit due to a unit increase in B's net demand for access. Laffont, Rey and Tirole (1998) discuss, in more detail, the implications of ECPR in this setting. They show, in particular, that applying ECPR in this context softens the price competition. That is, even if the networks are sufficiently substitutable in a symmetric and unregulated industry, they can obtain the monopoly profit by agreeing on a suitable access charge when they are subject to ECPR. The reason for this is that a high access charge under ECPR gives commitment to a collusive, high retail price. In other words, when the access charge is given at the level to sustain monopoly profits, imposing ECPR would only prevent the networks from lowering their retail prices.[16]

b) Extensions of the Basic Result

(1) Two-Part Tariffs

With a linear retail price assumed so far, a firm could not increase its market share without affecting the access deficit. Assume now that the networks can employ two-part tariffs with a fixed fee f_i and a usage fee p_i. A consumer's surplus can be written by $u_i = v(p_i) - f_i$ in this case. The networks now can use a fixed charge to build market shares without increasing their access payment. Laffont, Rey and Tirole (1998) show that the usage price would be set at the average marginal cost. The fixed fee would be set at the net marginal cost of adding a customer plus the Hotelling markup. They show that, contrary to the linear pricing case, the symmetric equilibrium profit would be independent to the access charge. This means that collusion cannot be sustained in the way of the linear pricing case. Laffont, Rey and Tirole (1998) point out that this result may be due to the homogeneity of consumer demand, though.

(2) Price-Discrimination

Suppose now that the networks discriminate the retail prices according to whether the call is on-net or off-net. Laffont, Rey and

[16]See Valetti and Estache (1998) for this interpretation.

Tirole (1998) show that a high access charge does not facilitate collusion in this case. Their intuition is analogous to the two-part tariff case. Since the access deficit depends on the quantity of off-net calls, which depends on the off-net prices, a network can use its on-net price to build its market share without increasing its access deficit. Therefore, a high access charge does not facilitate collusion.[17] As price discrimination distorts the substitution between on-net and off-net calls, the welfare implications of price discrimination are found to be ambiguous. However, it is shown that if the networks are poor substitutes and the access charge is higher than the terminating cost, price discrimination may enhance the social welfare, compared to the linear pricing case.

(3) An Asymmetric and Regulated Industry

Armstrong (1998) also presents an analysis of an alternative phase of the industry. In this setting, it is assumed that the retail price of the network A be regulated at p_A. While the network B is unregulated, it is assumed that B should charge a lower price than p_A if it is to attract any customer, that is, $s(0)=1$. The latter assumption is intended to capture the asymmetric situations faced by the 'incumbent' (A) and the 'entrant' (B). A customer may face a significant switching cost when he/she switches to B. In this setting, the networks have conflicting incentives in choosing the access charge.

Since p_B is always lower than p_A, the net number of calls from B to A (which was denoted by $z(p_A,p_B)$) is always positive. It is assumed that B's market share is lower than 1/2. Then, $z(.)$ is shown to be lower for a higher p_B. The profit function for B is convex in t so that $z(.)$ is lower for a higher t and, therefore, B would charge a higher retail price when t is higher. B prefers a lower access charge as a higher p_B would lead to a lower market share.

What would be a socially optimal access charge in this case? Since the networks have conflicting incentives about the access charge, a collusive outcome may not result. Rather, the case is similar to the one-way access with opportunity cost. Therefore, one might expect that the optimal access charge would be closely related to ECPR (see the one-way access part of this survey).

[17]See also Laffont and Tirole (2000, p. 202) for more detailed explanation.

Indeed, Armstrong (1998) shows that the optimal access charge consists of A's terminating cost and the opportunity cost, minus the subsidy on access to overcome B's market power. Hence, the access charge would be higher or lower than the direct cost (of the incumbent), depending on the incumbent's profitability from its own service and the entrant's market power. The author concludes that the optimal policy in this setting is analogous to the one-way case, except that the entrant's net demand (not gross demand) for access should be used.

c) Land-Mobile Competition

Wang, Yoon and Jeon (1999) point out that the previous models cannot adequately capture the situations in a land-mobile interconnection. First, they allow a consumer to subscribe to both networks (so that the networks can be complementary sometimes). Second, they consider two networks with different costs. They do not impose the reciprocity but the assumption of balanced calling pattern is maintained.

There are three stages of the game. First, consumers make the subscription decision. Access charges are set in the second stage, while retail prices are set in the third. They analyze three alternative regimes for the second stage, namely, the regimes of non-cooperative, collusive and regulatory determination of access charges is efficient.

They find that the collusive regime, in which two firms maximize their joint profit, results in each firm setting its access charge at its marginal cost. In this regime, no firm has the incentive to raise its rival's cost since one firm's access revenue is just the other's access payment. In the non-cooperative regime, each network does not consider the effect of its access charge on the retail revenue. This leads to access charges higher than marginal costs. The regulator would set access charges below marginal costs to offset firms' market powers in the retail sector.

Retail prices are shown to be the highest in the first regime, due to the double marginalization effect. They are set at monopoly levels (with perceived marginal costs) in the second, collusive regime. In the regulatory regime, the retail prices are set at the perceived marginal costs.

C. Issues of Internet Interconnection

a) Preliminaries

Two-way access situations may also arise from the area of interconnection between carriers that provide networks for Internet. Internet consists of networks with various sizes. An individual network can be directly connected to the subscribers, while others provide only long-haul transmissions regionally or nationally. Some of these networks also have international cables for the global connectivity. All of these various types of networks are interconnected, directly or indirectly, to form Internet.

To examine the nature of issues in this variety of interconnection types, we first classify the networks into two groups.[18] First group consists of carriers (A,A',*etc.*) that have only subscriber access networks. Carriers (B,B',*etc.*) with regional, national or global transmission networks (but no subscriber networks) constitute the second group. A network in this group (B) carries the traffic originated by A to the websites connected to itself, or passes it to the network A', connected to itself, to reach customers of A'. B also can pass the traffic to B'. Finally, it should be noted that B can also attract its own customers, although it needs to interconnect with, or lease a subscriber line from, A to do so. See the next subsection for more discussion. In reality, of course, there are many carriers that are in both groups. These carriers can be denoted by A/B, A'/B', *etc*. Also, it should be noted that carriers in the same group may be quite different in the coverage of their networks. Cremer, Rey and Tirole (1999) distinguish between an Internet Service Provider, ISP (a small, regional network of type A/B) and an Internet Backbone Provider, IBP (a larger network that provides long-haul transmissions for its own customers and ISPs).

IBPs typically used to interconnect with each other by 'peering' arrangements (on a settlement-free basis)[19] at public access points.

[18]We do not claim the following classification of types of Internet interconnection is exhaustive.

[19]Laffont and Tirole (2000, p. 270) explain that, by peering, the carriers 'accept all traffic that is destined to their own customers, the customers of their customers, and so on' and that, currently, the peering arrangements are of bill-and-keep type. Other authors such as Cukier (1998) directly adds the settlement-free feature in the definition of peering. We will use the term to roughly mean that each carrier allows the direct routing of all of the other's traffic to its customers, on a settlement-free basis.

These access points usually also provide a global connectivity to the participating carriers. Therefore, if an IBP or an ISP connected to an IBP peers with other IBPs through a public access point, it gains access to the global Internet. However, as Internet industry is more commercialized and network sizes differ more, IBPs tend to prefer private arrangements for interconnecting with smaller IBPs or ISPs. This means the smaller IBPs or ISPs should pay some access charges or, otherwise, they might lose a global connectivity. Access pricing for Internet interconnection then would become a more imminent issue for the future of Internet. Before discussing various types of Internet interconnection, we can assume away ($A-A'$) type of interconnection for Internet services. A typical Internet traffic originated by a subscriber of A generally goes through (separate equipments to process data traffic and then) some Internet backbone(s) to reach a subscriber of A'.

b) Types of Internet Interconnection

(1) Types ($A-B$) and ($A/B-B'$)

To begin with, we consider the type ($A-B$). The network A always needs this to access Internet. In most cases in reality, however, A has also its own transmission network (call it B) to provide its own Internet service. Therefore, a more relevant case to discuss would be when B', a carrier independent from A, needs the interconnection ($B/A-B'$) to attract its own subscribers using dial-up access.[20] The networks A/B and B' will then compete for the same downstream (Internet service) market. That is, this case is analogous to one-way access. Despite this similarity, however, the retail service is different in nature from the POTS. Hence, most of the countries have applied different regulatory approaches to this case from those applied to, say, interconnection between a local carrier and a long-distance carrier.[21] Further theoretical researches may be needed to examine the economic incentives for this situation.

Next, we can consider a hypothetical situation where B' chooses not to attract the final consumers but only operate transmission

[20]Here, the interconnection would normally occur between A and B' but not between B and B'.

[21]For example, the traffic exchange in this case is currently on a settlement-free basis in Korea.

networks. The network A/B then wishes to interconnect with B' to enhance its connectivity.[22] Without retail market competition between the networks, the problem is similar to that of make-or-buy decision-making by the network A. In reality, however, given the relatively low entry barrier of Internet services market, we do not expect to see many of these cases. For the same reason, we would not discuss the type ($B-B'$).

(2) The Type ($A/B-B'/A'$)

This case is basically similar to the two-way access models of the previous subsection. Access pricing problem thus could be analyzed using a basically similar setting. However, analyzing this problem clearly would require different assumptions. This is because of the differences in the nature and the structure between the retail prices for Internet and telephony.

Huston (1999) concludes, after extensively discussing possible alternatives,[23] that 'there are no soundly based models of financial settlement in widespread use today.' He particularly notes that the retail price of Internet service does not typically reflect the end-to-end service provision, contrary to the most retail rates for the telephony service. For example, when a user requests and then downloads a large amount of data from a remote website, he/she usually pays for the usage of only a limited portion of his/her network usage that is under the direct or indirect control by his/her ISP. Also, various types of pricing options, including a fixed monthly fee, are currently offered by interconnecting firms. Huston (1999) notes that these and other cost-related or technical reasons make it hard to even identify which of the receiver and the sender should pay the access fee. The increasing need for a premium Internet service, provided on an end-to-end guarantee of QoS, can be expected to alleviate the problem in the future.

Laffont, Marcus, Rey and Tirole (2001a) also identify three reasons how the settlement issues in Internet interconnection are different from those in telecommunications; differences in technical characteristics of Internet and traditional telecoms networks, non-existence of a global regulatory authority for the Internet, and the different structure of retail pricing. The last point refers to the

[22]In this case, the interconnection occurs between B and B' but not between A and B'.

[23]Srinagesh (1995) is also an excellent source of information.

fact that the retail pricing for Internet typically requires receivers of the traffic pay for the service as well as the senders. In contrast, the receivers do not pay for receiving calls in the two-way access models for the traditional telecommunications.

Considering a Bertrand competition for end users between IBPs, assuming that end users only receive traffic while websites only send them, Laffont, Marcus, Rey and Tirole (2001a) set out the 'off-net-cost' pricing principle. That is, in a competitive equilibrium, IBPs charge $p=c^T - a$ to the end users and $\tilde{p}=c^0+a$ to the websites.[24] Laffont, Marcus, Rey and Tirole (2001b) further derive Ramsey access charges. We do not cover this analysis in detail here.

Focusing on a different aspect of the issue, Cremer, Rey and Tirole (1999) models this type of interconnection. The main theme of their analysis is how the strategy of degrading the quality of interconnection can be used by a dominant IBP. In particular, it is shown that when the two backbones competing for unattached customers, interconnect, the firm with a larger installed base of customers prefers a lower quality interconnection than the smaller one. Interconnection charge in their model is not present (as in a settlement-free arrangement) or is determined by a bargaining game, in the form of a smaller firm's payment to the larger one for subsidizing the latter to provide a higher level of connectivity.

IV. Conclusions

We proposed and utilized a simple model to review relay interconnection literatures. Without any complications of scale economies and opportunity costs *etc*., marginal cost pricing of interconnection charge is optimal from a society's point of view. When incumbent sets the interconnection charge, it may or may not foreclose entrants depending upon degree of entrant's efficiency and forms of interconnection charge. When an entrant is more efficient than incumbent and interconnection charge is non-linear, incumbent turns out not to foreclose the entrant. Of course, it is inevitable for incumbent to foreclose an inefficient entrant.

[24] c^0 and c^T stand for the costs of origination and termination for IBPs, respectively.

Incumbent may foreclose an efficient entrant when interconnection charge takes the form of linear pricing and when efficiency gain is not much compared to the profit loss caused by double marginalization.

When there are opportunity costs for incumbent to interconnect, then opportunity cost should be paid by the entrant according to the efficient component pricing rule. When there are economies of scale in bottleneck provision, Ramsey pricing comes to rescue. Since Ramsey and ECPR solve a very similar problem, they turn out to be the same in symmetric cost and demand cases. In various situations such as large monopoly profit and market creation by entrant etc, ECPR should be modified. In an extension of Ramsey spirit, the global price caps are suggested by Laffont and Tirole (1996). They use weights between interconnection and final sales to give proper incentives to incumbent for socially optimal mix of services provision. However, optimal weights are not to be found easily since it should be based on demand forecast.

Next, we have reviewed the current status of the two-way access theory. There have been some theoretical results that may have important policy implications. First, a case has been made to call for at least a regulatory scrutiny in the access pricing, even when the market competition exists between symmetric networks. In this case, access pricing can be used to promote collusive retail prices. A regulator may have to refrain from applying ECPR in this context. The use of two-part tariffs or price discrimination can sometimes help, as they enable firms to compete in market shares without affecting their access payments. Besides, the non-cooperative setting of access charges may prove more harmful to the society than the collusive determination case.

Then, finally, we identified various types of Internet interconnection and discussed their characteristics. We presented main results by Laffont, Marcus, Rey and Tirole (2001a, b) on the pricing issues of Internet interconnection.

We feel that more researches are required for the further refinement of the theory of two-way access, though. Notably, as was already noted by some authors, a network competition model allowing a more generalized calling pattern would be necessary. One could also explicitly consider the network externality in the model. Various issues identified for the access pricing in Internet interconnection may also provide many useful research topics.

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