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A SIMPLE APPROACH TO NETWORK COMPETITION

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This paper develops a simple model of competition among interconnected networks. Access fees are determined either by a regulator or by competition. We show that the price is higher when they compete in both access prices and final tariffs non-cooperatively than when the access fees are regulated. We also show that incentives to collude are higher when access fees are regulated to the level of marginal cost of access services. Thus it is ambiguous to judge the net effect of competition on prices and relevant regulations are necessary to enhance welfare effects.

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1. INTRODUCTION

The purpose of this paper is to develop a simple model of competition between interconnected networks providing differentiated services. In the network industry it typically requires access to rival networks to provide services or to satisfy its customers. Such examples include networks for electricity transmission, gas transportation, telecommunication access, and banks' ATM networks, etc.[1] This feature is what distinguishes the network industries from others in that interconnected firms try to take a dominant position not only by competing in prices but also by deteriorating competing network by charging excessive access fees, thereby raising rival's costs.

Access prices can be determined in two ways in general, which differ depending upon regulatory environment. Possibilities include; 1) the regulator determining access

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[1] This open network architecture is typically motivated by the existence of substantial network externalities. In this paper we do not model network externalities. The purpose of the paper is not to explain why they choose to be interconnected but to study what will be networks' behavior once they are interconnected.

charges for the best interests of social welfare; 2) the networks having discretion over strategically chosen access charges.[2] In this paper we analyze the effect of different way of determining access charges on final tariffs in the context of network competition, such as mandated cost-based access pricing rules and non-cooperatively determined access charges. In this regard, we study whether unregulated competition improves welfare via fierce competition among networks.

We propose a model of network competition where network products are differentiated and networks compete in prices a la Bertrand. Networks' providing services completes in two stages; in the first stage, access charges are determined, in the second stage, final tariffs are determined. As mentioned, we analyze two different ways of determining access charges.

First, we study the case in which an arbitrarily chosen reciprocal access charges are given to networks in the first stage and they compete non-cooperatively in prices in the second stage. We investigate how the choice of access charges affects the final tariffs and what should be the optimal level to enhance welfare. Second, we study the case in which networks set their access charges non-cooperatively (possibly asymmetrically) in the first stage. It analyzes a two stage game where networks first choose access charges and second choose tariffs. We will compare non-cooperatively selected access charges with the optimal access charges and marginal costs of providing access. We will also compare final tariffs under a two stage game with that with optimal (or cost-based) access charges and investigate whether unregulated competition affects prices in the best interests of customers. One of this paper's main focus is to investigate how discretion over access charges allowed to networks affects equilibrium. Networks revenue flows come from two different income streams; revenues by collecting tariffs from customers and revenues by collecting fees from the rival network for providing access services. When network products have large substitutability, excessive access charges affect profits in two opposite directions. First it raises its rival's costs and thereby its prices, which let the firm have the edge on its rival in competing prices. But rival's high prices will shrink customers relative to their own customers. This may cause deficits in access revenues. Thus in the setting of a two stage game, the problem of selecting access charges is very subtle. In this paper we will show that there always exits an equilibrium.

We also study how unfettered competition among networks changes incentives of tacit collusion compared to limited competition where the regulator set access charges close to optimal level. For this purpose we analyze an infinitely repeated game in which firms interacts infinitely many times. We investigate whether the network's incentive to collude tacitly with its rival when the access charges are regulated closely to the marginal costs of giving access.

[2] Armstrong *et al*. [1] categorizes these possibilities in four groups. Their categorization, however falls into two groups

Armstrong *et al*. [1] and Laffont *et al*. [3] are related to, but distinct from this paper. Armstrong *et al*. studies a model in which a dominant network controlling a essential facility (or bottleneck facility) should provide mandated access to entrants which do not have its own network. They give a rationale of the Efficient Component Pricing Rule(ECPR) by analyzing optimal access pricing problem similar to the one discussed in this paper. Their approach, however, is quite distinct from ours since we consider competition between two independent networks with its own networks. Laffont *et al*. is similar to ours in that they also pay attention to competition between interconnected networks. They develop a model of differentiated networks a la Hotelling and analyze how access charges affect the competitiveness of the industry. They investigated various issues including entry and nonlinear pricing, which is not covered in this paper. Their results, however, can not be applied to the study of competition between networks with large substitutability, which is a crucial weak point.

The article proceeds as follows. Section 2 explains the model. Section 3 analyzes issues in three subsections. In Section 3.1, we investigate the case where the access charges are arbitrarily chosen by a regulator. In Section 3.2, we study a model of a two stage game in which access charges are selected non-cooperatively. In Section 3.3, we study a model of infinitely repeated game to study tacit collusion. Section 4 gives conclusive remarks.

2. MODEL

We assume that there are two interconnected networks in the market. Two vertically integrated firms provide network services which are close substitutes, but the level of substitutability is not perfect. Networks compete in prices a la Bertrand and are assumed to have the following market demands;

$$q_1 = m - p_1 + np_2,\ \ q_2 = m - p_2 + np_1, \tag{1}$$

where $0 < n < 1$. This model differs from Laffont *et al*. [3] where the networks are differentiated a la Hotelling. Laffont *et al*. also studies competition among interconnected networks, and analyzes how networks'decisions on access fees and tariffs affect consumers' choices and thus equilibria. We assumed away consumers' behavior using the simplifying assumption of linear demands. There are literature on network competition using the linear demand structure, e.g., Armstrong *et al*. [1]

Armstrong *et al*. differs from ours in that they study how the efficient access fees are determined if there are one vertically integrated network which controls the access to the bottleneck facilities to its competitors without fully integrated networks.

We assume that two networks have the same cost structure. There is a fixed cost of providing services, $f \geq 0$ which includes network installing costs.[3] Throughout this paper it is assumed that the fixed costs are small enough for two networks to survive. Providing a service to its own customers incurs a marginal cost of c using its own networks. The marginal cost c consists of three parts. Consider customer A makes an phone call to customer B who subscribes to the same network. Then the network incurs a marginal cost c_0 per call at the point where A uses the service and also at the terminating ends of the call, i.e., where B receives the call. Furthermore the network incurs a cost c_1 in between. The total marginal cost of a call is thus $c \equiv 2c_0 + c_1$.

To provide interconnection services, it is necessary to provide essential input services to its competing network. Networks charge fees for this service called interconnection charges or access charges. In the former case, a network pays as much for terminating a call on the competing network as it charges for terminating a call originated on the competing network. In contrast of reciprocal access fees, firms may set their access fees non-cooperatively and therefore possibly asymmetrically in nonreciprocal access pricing.[4]

The following assumption is very crucial for the analysis and is a modified version of the assumption of balanced calling pattern in Laffont *et al*. [3]

Assumption 1: *The number of calls originating on a network and completed on the same network is equal to the demand for the service.*

In Laffont *et al*. [3] the balanced calling pattern is assumed in terms of the percentage of services, and here it is assumed in terms of the number of services. Both assumptions imply that flows in and out of a network are balanced under the same tariff of network services.

Each network's objective is to maximize profits. They compete in tariffs in markets. Let a_i be the unit access fee to be paid for interconnection by a competing network to the network *i*. and p_i be the tariff. The network *i*'s profit is given by

$$\Pi_i(p_i, p_j, a_i, a_j) = [(p_i - c)q_i - f] + [(a_i - c_0)q_j - (a_j - c_0)q_i]\,. \tag{2}$$

[3] Fixed costs like network installing costs are usually joint and common costs in network industry. When there is a potential entrant who needs to pay fixed costs of this type to provide services and the entrant's networks can be used by the incumbent, then strategic behavior of the incumbent may be quite different from other cases in typical industry. In this paper the fixed costs play no interesting role.

[4] In this paper, our main concern is both way interconnection. There is another type of interconnection, e.g., one way interconnection charges paid by the inter-exchange carriers to the local exchange carriers. Armstrong *et al*. [1] analyzed this type of interconnection charges.

The above profit excludes both a selective interconnection approval and tariff discrimination. The network cannot deny the interconnection request by its rival, and strategically selective approval is forbidden in many countries. Furthermore the network is not allowed to discriminate tariffs between on-net calls and off-net calls.

3. MAIN RESULTS

This paper analyzes a competitive market environment in which regulation on final tariffs is withdrawn. And any type of explicit collusion among networks on final tariffs and access fees is not allowed. However we analyze the situation that access fees are determined by a regulator and that networks tacitly collude with each other. We consider two different market environments; First, access fees are determined by a regulator and given these firms competes non-cooperatively in markets; Second, in the first stage firms engage in access fee pricing competition and in the second stage they competes in the final tariffs. We will study how these two different market environments affect final tariffs.

3.1 Regulated Access Pricing

In this section, we first analyze networks' final tariff competition given an reciprocal access charge set by a regulator. A network pays as much for termination of a call on the rival network as it receives for completing a call originated on the rival network. This case reflects the recent decision by US regulator (FCC) and UK regulator (Oftel).

Let the reciprocal access fee be a^r In this case, two networks' profits are given by

$$\Pi_i(p_i, p_j, a) = [(p_i - c)q_i - f] + [(a^r - c_0)q_j - (a^r - c_0)q_i]\,. \tag{3}$$

It says that if the access charge is greater than the marginal costs of providing access, i.e., $a^r > c_0$ then profits from providing access get bigger as it terminates more calls on nets than off nets. In case networks' services are substitutes, it depends on tariffs each network imposes. Similarly in Laffont *et al*. [3], access revenue increases as its tariff gets greater than rival's tariff. The next Proposition 1 is a direct outcome of a Bertrand competition.

Proposition 1: *Under a regulated access fee* a^r*, there is a symmetric Nash Equilibrium;*

$$p_1 = p_2 = p^* = \frac{m+c}{2-n} + (a^r - c_0) \times (\frac{n+1}{2-n})\,. \tag{4}$$

Equilibrium prices in Proposition 1 consist of two parts. The first part is determined by the final tariff price competition $\frac{m+c}{2-n}$ and the second part is determined by additional costs incurred by giving access $(a^r - c_0)\times(\frac{n+1}{2-n})$. That not only the costs of producing the final service but also the costs of giving essential inputs to its rival are crucial in determining the final tariff is what differentiates the network industry competition from the case of other industry. This is one of the reasons that make one to doubt if usual conclusions of introducing more competitions to markets, e.g., lower prices, are valid in the network industry. If the access charge is set at $a^r = c_0$, then the final tariff is the same as the one under the typical differentiated product Bertrand competition.

What is the most relevant access charge is not the main concern of this paper. Proposition 1, however, has an interesting policy implication with regard to a relevant access charge pricing. The level of relevant or optimal access charge must depend on the objective of the regulator, but it is often told that one of the main objectives of the regulator is to make networks to function as a public service that should abide by public welfare.[5] Let the regulator be a benevolent third party which sets the access charge to maximize consumer welfare under the constraint that networks break even.[6] Let this access charge be denoted by a^R and p^R be denoted by the corresponding symmetric equilibrium price. Then

$$a^R = c_0 + (\frac{2-n}{n+1})[p^R - \frac{m+c}{2-n}]. \tag{5}$$

Given demand conditions and costs, each network earns positive profits if $p^* = \frac{m+c}{2-n}$. Thus it must be that $p^R < \frac{m+c}{2-n}$, and this implies that $a^R < c_0$. The following Proposition 2 thus holds.[7]

Proposition 2: *Unless the predetermined access charge is set sufficiently low,* $p^R < p^*$. *Furthermore* $a^R < c_0$.

[5] In many countries, regulators require networks to maintain the universal service as one of conditions of their license. This is one of evidences that networks are regarded as a public service as well as a profit pursuing firm.

[6] It is often assumed that the regulator maximizes consumer surplus satisfying zero profit conditions, e.g., [3], [4]. It is reasonable if regulated firms are public utilities.

[7] Proposition 2 confirms Proposition 3 of Laffont *et al*. [3]

Notice that Proposition 2 does not imply that each network faces deficits under a^R which are lower than the marginal costs of providing access. At equilibrium, flows in and out of each network are balanced, and thus there is no deficit in access revenue. Proposition 2, however, implies that the regulator can effectively control the tariff by regulating the access fee.

3.2 Two Stage Network Competition

In this section, we assume that the networks set access fees non-cooperatively, and analyze a model of two stage games where the networks first set access fees and second compete in tariffs.

We first look at the second stage, i.e., price competing stage, taking nonreciprocal access charges as given, and then study the first access charge competition stage backward. For given access fees a_1, a_2, network *i*'s profit maximizing first order condition is given by

$$\frac{\partial \Pi_i}{\partial p_i} = \frac{\partial}{\partial p_1}\{(p_i - c)(m - p_i + np_j) + [(a_i - c_0)(m - p_j + np_i) - (a_j - c_0)(m - p_i + np_j)]\} = 0, \ i = 1,2 . \tag{6}$$

From these conditions, we derive each network's best responses as follows.

$$p_i = \frac{1}{2}(m + np_j + c + n(a_i - c_0) + (a_j - c_0)), \qquad i, j = 1,2 . \tag{7}$$

Thus the second stage Nash equilibrium given access charges is

$$p_i = \frac{m-c}{2-n} + \frac{3n}{4-n^2}(a_i - c_0) + \frac{2+n^2}{4-n^2}(a_i - c_0), \ \ i, j = 1,2 . \tag{8}$$

Using backward induction, we can express each network's profit in terms of access fees. Then we can easily find the subgame perfect Nash equilibrium for this two stage game. And it isn't difficult to show that there is a symmetric equilibrium. Let the symmetric access charges be denoted by $a_1 = a_2 = \hat{a}$. Then in this two stage game the final tariff is determined by

$$p_1 = p_2 = \hat{p} = \frac{m+c}{2-n} + (\hat{a} - c_0) \times (\frac{n+1}{2-n}) . \tag{9}$$

Notice that the difference between $\hat{p}$ and p^* differs only from the way how access charges are determined; determined by a regulator a^r or by the market $\hat{a}$. And it is worth noticing that the equilibrium price increases as the equilibrium access charge increases. In order to see if deregulating the network industry results in lower consumer prices, it suffices to compare $\hat{a}$ with c_0 since the regulator sets access charges below the marginal costs. Proposition 3 shows that the access charge determined by market forces is above the marginal costs. We first prove the following two lemmata.

Lemma 1: $\dfrac{\partial^2 \prod_i (a_i, a_j)}{\partial {a_1}^2} < 0$

Proof : $\prod_i (a_i, a_j)$ is a quadratic function with regard to a_i, and thus it suffices to show that the coefficient of a_i^2 is negative. The coefficient of a_i^2 is

$$\begin{aligned} &-(\frac{3n}{4-n^2})^2 + \frac{3n}{4-n^2} \times \frac{(2+n^2)n}{(4-n^2)} - \frac{(2+n^2)}{(4-n^2)} + \frac{3n}{4-n^2} \\ &\qquad = \frac{3n^2(n^2-1)}{4-n^2} + \frac{2(n^2-1)}{4-n^2} < 0. \end{aligned} \tag{10}$$

since $n < 1$. This completes the proof. Q.E.D.

Lemma 2: $\left. \dfrac{\partial \prod_1}{\partial a_1} \right|_{a=c_0} > 0$.

Proof : Since

$$\begin{aligned} \prod_i &= p_1(m - p_1 + np_2) + (c_0 - c - a_2)(m - p_1 + np_2) + a_1(m - p_2 + np_1) \\ &\quad - c_0(m - p_2 + np_1) - f. \end{aligned} \tag{11}$$

the partial derivative of $\prod_i$ with regard to a_i at the symmetric equilibrium is given as follows ;

$$\begin{aligned} &\frac{\partial \prod_1}{\partial a_1} = \frac{3n}{4-n^2}(m+(n-1)p) + p(\frac{n(2+n^2)}{4-n^2} - \frac{3n}{4-n^2}) \\ &+ (c_0 - c - a)(\frac{n(2+n^2)}{4-n^2} - \frac{3n}{4-n^2}) + (m+(n-1)p) + a(\frac{3n^2}{4-n^2} - \frac{2+n^2}{4-n^2}) \\ &+ c_0(\frac{2+n^2}{4-n^2} - \frac{3n^2}{4-n^2}) = \frac{(4-n)(1+n)}{4-n^2}(m+(n-1)p) \\ &+ [(p + c_0 - c - a)n + 2(a - c_0)] \times \frac{n^2-1}{4-n^2}. \end{aligned} \tag{12}$$

Evaluated at $a_1 = a_2 = a = c_0$, then

$$\left.\frac{\partial \Pi_1}{\partial a_1}\right|_{a=c_0} = \frac{(4-n)(1+n)}{4-n^2}(m+(n-1)p)+[(p-c)n]\times\frac{n^2-1}{4-n^2}. \tag{13}$$

Since $m+(n-1)p = \frac{m+nc-c}{2-n}$ and $p-c = \frac{2+cn-c}{2-n}$, $m > c$ implies that $m+(n-1)p = p-c > 0$. Thus

$$\begin{aligned}\left.\frac{\partial \Pi_1}{\partial a_1}\right|_{a=c_0} &= (\frac{m+nc-c}{2-n})(\frac{4+3n-n^2+n^3-n}{4-n^2}) \\ &= (\frac{m+nc-c}{2-n})(\frac{4-n^2+n(n^2+2)}{4-n^2}) > 0.\end{aligned} \tag{14}$$

That implies the proof. Q.E.D.

Proposition 3: *In two stage games, the equilibrium access charge* $\hat{a}$ *is bigger than the marginal cost* c_0. *Furthermore,* $a^R < c_0 < \hat{a}$.

Proof: By Lemma 1, Π_i is strictly concave for *i=1,2*. With Lemma 1, Lemma 2 implies that $\hat{a} > c_0$. Since two networks are symmetric, this completes the proof. Q.E.D.

Since the equilibrium tariff increases with the access charge, the following Proposition follows.

Proposition 4: *Let* $\overline{p}$ *be the equilibrium price when the access charge is set at the marginal cost by the regulator, i.e.,* $\overline{p} = \frac{m+c}{2-n}$. *Then* $p^R < \overline{p} < \hat{p}$.

The networks has an incentive to lower the price in order to attract more consumers when markets are more competitive, but at the same time has an incentive to increase rival's prices by increasing access charges. The networks are not only competitors in the final product market but also input suppliers as providers of essential facilities. When networks compete, there must arise a problem of interconnection. If the costs of interconnection is determined by market forces, then each network has an incentive to impose access charges higher than the marginal costs and thus to increase rival's prices. Proposition 3 says that equilibrium access charges are above marginal costs and thus equilibrium prices are more than the desired level p^R. Thus it seems that when markets become deregulated and entries get easier, well designed limited competition tightly overwatched by a third party would improve welfare. Especially in the network industry how to use the bottleneck facility must serve the public's purpose even if it is privately owned. This may provide a rationale why the policy of open access and regulatory control over access charges is often a cornerstone of telecommunication competition. We will, however, discuss in the next subsection that in the long-run unfettered competition between networks in every stage of providing services may well serve the best interests of the public.

3.3 Tacit Collusion

In the previous section we show that the more competitive environment brings higher tariffs and thus negative effects to consumer welfare. In this section, we discuss the other side of deregulating the network industry. We will argue that a firm's incentive to collude tacitly with its rival on the tariff is greater when the access charges are regulated close to marginal costs of providing access. For this argument we consider infinitely repeated interactions among networks.

It is well known that the cooperative outcomes can be achieved as an equilibrium for long-lived agents even if the cooperative outcome is not an equilibrium of the stage game. We will argue that in the limited competitive environment where the access charges are regulated at the marginal costs myopic firms that have no incentive to cooperate in the more competitive environment can choose to cooperate. That is, it is easier for firms to collaborate in the limited environment in the sense that even more myopic firms have incentives enough to sacrifice higher stage game payoffs.

We will first give a numerical example based on the model used in the previous sections and then give the formal results.

Example: We assume that $m=1, n=1/2, f=0, c=0$ for a numerical example. In fact these are harmless assumption and the results are robust. We first calculate the equilibrium when the access charges are regulated. Without loss of generality, we consider $\overline{p}$ in which the access charge is set at the marginal costs, that is, $a^R = c_0$ in the first stage. In the second stage, each firm sets

$$\overline{p}_1 = \overline{p}_2 = \frac{m+c}{2-n} + (a-c_0)\times(\frac{n+1}{2-n}) = \frac{2}{3}(1+c) = \frac{2}{3}\,. \tag{15}$$

And the profits are $\Pi_1^R = \Pi_2^R = 4/9$. If they cooperate in the second stage, they set prices to maximize joint profits, that is,

$$(p_1, p_2) \in \arg\max_{p_1,p_2} (p_1 - c)(1 - p_1 + \frac{1}{2}p_2) + (p_2 - c)(1 - p_2 + \frac{1}{2}p_1)\,. \tag{16}$$

Let p^m be the collusive price, and then $p^m = 1$. Let Π_i^{RC} denote the firm *i*'s cooperative profits with the regulated access charge. As usual $\Pi_1^{RC} = \Pi_2^{RC} = 1/2 > 4/9$. However these profits cannot be achieved as an equilibrium profits by myopic firms. This outcome cannot be attained as an equilibrium of the stage game played only once. It is well-known that if firms interact repeatedly and they focus on the collusive outcome, then the cooperative profits can be achieved at equilibrium in case of long-lived agents.

Now suppose that two firms interact infinitely many times, and both firms discount future profits. Let β_1 and β_2 denote theses discount factors and assume that $\beta_1 = \beta_2 = \beta$. We consider the infinitely repeated game of Bertrand competition with the discount factor β. At each date t, the firms choose their prices (p_{1t}, p_{2t}) simultaneously given access charges to maximize the present discounted value of its profits; $\sum_{t=1}^{\infty} \beta^{t-1} \prod_i (p_{1t}, p_{2t})$. The price strategy p_{it} depends on the history $H_t \equiv (a^1, a^2, ..., a^t)$, where $a^j = (p_{1j}, p_{2j})$. It is required that strategies form subgame perfect equilibrium in that for any history at date t, firms' strategy from date t on maximizes the present discounted value of profits from that date on. The punishment strategy is crucial to achieve the cooperative outcome as an equilibrium. We only consider the grim trigger strategy;

$$s_i(\phi) = p^m \quad \text{and}$$
$$s_i(H_t) = \left\{ \begin{array}{l} p_i = p^m \text{ if } a^\tau = (p^m, p^m), \tau = 1,2,....,t \\ p_i = \overline{p}_i \text{ otherwise} \end{array} \right\}. \tag{17}$$

In charging $p_i = p^m = 1$, each firm earns 1/2 in each period. By deviating from this price, the deviating firms can earn higher profits during the deviation period, but this deviation triggers a halt in the cooperation forever. The best response to the other firm's price $p^m = 1$ is to set $p_i = 3/4$. Let Π_i^{dR} denote the deviating firm's profit when the access charge is regulated. As a result the deviating firm's profit during the period of deviation is $\Pi_i^{dR}(p_i = 3/4, p_j = p^m = 1) = 16/9$, but it receives $\Pi_i^R = 4/9$ forever more. Thus, if

$$(\frac{1}{1-\beta})\frac{1}{2} \geq \frac{9}{16} + \frac{4}{9}(\frac{\beta}{1-\beta}). \tag{18}$$

which follows that $\beta \geq 3/5 \equiv \beta^R$, then the strategy in which each firm's strategy is the grim strategy is a subgame perfect Nash equilibrium.

Now we consider two stage network competition of Section 3.2. In the first stage they noncooperatively set access charges and in the second stage they compete in the final tariff. The noncooperative outcomes are $p_1^C = p_2^C = 2/3 + 5(a^c - c_0)$ in the second stage, and in the first stage the equilibrium access charges are determined by $a_1^C = a_2^C = a^c = 10/69 + c_0$. Therefore $p_1^C = p_2^C = 2/3 + 5(a^c - c_0) = 76/69$. In the two stage game each firm's equilibrium profit is $\Pi_i^C(p_1^C, p_2^C, a_1^C, a_2^C) = \frac{2356}{4761} \cong 0.494854$. Notice that $\Pi_i^C > \Pi_i^R$, *i=1,2*. In the two stage game the cooperative profits and the prices are the same as in the regulated game since access revenues are cancelled out. We assume that they set the noncooperative access charge even if they decide to cooperate. Thus also in this case the cooperative prices are $p^m = 1$ and the cooperative profits denoted by Π_i^{CC}, $i = 1,2$ are 1/2.

Now we consider again the infinitely repeated game of two stage Bertrand competition.

We assume that firms are able to deviate from the cooperative tariff only. That is, we assume that they do not try to deviate from access charges since it is detected without delay. Thus the only difference between this game and the regulated access charge game is the level of access charge. As in the earlier game we only consider the grim trigger strategy;

$$s_i(\phi) = p^m \text{ and}$$
$$s_i(H_t) = \begin{Bmatrix} p_i = p^m \text{ if } a^\tau = (p^m, p^m)\tau = 1,2,....,t \\ p_i = p_i^C \text{ otherwise} \end{Bmatrix}. \quad (19)$$

Suppose that the firm 1 decides to deviate from the cooperative price. Then the firm 1 will choose the price p_1 such that

$$p_i = \arg\max[(p_i - c)q_1(p_1, p^m) - f] + (a^C - c_0)[q_2(p_1, p^m) - q_1(p_1, p^m)], \quad (20)$$

where $c = f = 0,\ a^C = 10/69 + c_0$. Notice that this problem of finding best response to p^m is more complicated than the case of regulated $a^R = c_0$, since the access revenue now affects the firm's strategic behavior. The solution is $p_1 = 37/46$ Let Π_i^{dC} denote the deviating firm's profit during the period of deviation, and then $\Pi_1^{dC} = 1094/2116 \cong 0.5170132$. Notice that $\Pi_1^{dR} = 9/16 > \Pi_1^{dC}$. For the grim trigger strategy being an equilibrium, the following should be satisfied;

$$(\frac{1}{1-\beta})\frac{1}{2} \geq \frac{1094}{2116} + \frac{2356}{4761}(\frac{\beta}{1-\beta}). \quad (21)$$

which follows that $\beta \geq \frac{170132}{221592} \equiv \beta^C \cong 0.7677713$. Notice that $\beta^C > \beta^R$.

The above example shows that the regulator's intervention in the access pricing procedure can facilitate tacit collusion. In other words, more competitive market structure, that is, introducing competition in every stage of providing network services cause a breakdown of collusion between networks. The next proposition shows that this observation is robust.

Proposition 5 : $\beta^C > \beta^R$

Proof: For each firm not to derivate from the cooperative behavior, the following inequality must hold ;

$$(\frac{1}{1-\beta})\prod^m \geq \prod^{dk} + \prod^k (\frac{\beta}{1-\beta}), \text{ where } k = C, R. \tag{22}$$

which follows that

$$\beta \geq \frac{\prod^{dk} - \prod^m}{\prod^{dk} - \prod^k} \equiv \beta^k(\prod^{dk}, \prod^k). \tag{23}$$

It is easy to see that $\frac{\partial \beta^k}{\partial \prod^{dk}} < 0$ and $\frac{\partial \beta^k}{\partial \prod^k} > 0$. Lemma 1 and lemma 2 implies that $\prod_i(a^C, a^C) > \prod_i(a^R, a^R) \quad \forall \quad i$. And $\prod_i^{dC} < \prod_i^{dR}$ since $[(p_i - c)q_i(p_i, p^m) - f] + (a^C - c_0)[q_j(p_i, p^m) - q_i(p_i, p^m)] \leq (p_i - c)q_i(p_i, p^m) - f \quad \forall$ $p_i \leq p^m$. This completes the proof. Q.E.D.

Proposition 5 shows that it is easier to collude when access fees are regulated to the level of marginal cost of providing access services. Proposition 4, however, shows that the final tariff with regulated access charges is lower than that with access charges determined by markets. Thus it is ambiguous to judge the net effect of competition. These imply that the introduction of competition to the network industry needs to accompany relevant regulations to enhance welfare effects.

4. CONCLUDING REMARKS

This paper proposes a simple model of competition among interconnected networks producing services with large substitutability. Networks charge fees to rival networks for providing access to its network, i.e., its essential facility. It is shown that the price charged by networks is higher when they compete in access prices and final service prices noncooperatively than when access charges are regulated by a regulator. In this sense, unfettered competition does not guarantee the increase of customer welfare via fierce price competition. It is also shown that the regulator's intervention in the access pricing procedure can facilitate tacit collusion. In other words, more competitive market structure, that is, introducing competition in every stage of providing network services may cause a breakdown of collusion between networks. Thus it is ambiguous to judge the net effect of competition. These imply that the introduction of competition to the network industry needs to accompany relevant regulations to enhance welfare effects which the pro-competitive policy is meant to foster.

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