Interconnection Agreement between Internet Service Providers and the Optimal Policy Intervention: The Case of Cournot-type Competition under Network Externalities

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Abstract

We derive the optimal subsidy policy for the interconnection agreement between two symmetric ISPs competing à la Cournot in a network service market. The interconnection quality is lower than the socially optimal level, as suggested by Crémer, Rey and Tirole (2000). In the model where the two ISPs compete in the domestic market, the optimal subsidy rate depends positively on the strength of network externalities. In the extended model where home and foreign ISPs compete in the home market, the optimal subsidy rate for the home government is higher than in the model where both ISPs are home firms.

Keywords: Internet service provider; interconnection quality; Cournot competition
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1 Introduction

The quality of interconnection is an important strategic instrument for competing Internet service providers (ISPs). In recent years, as the need for Internet traffic exchange in high speeds increases (for, e.g., Internet telephony, video conferencing, medical and management services etc.), the corporation through interconnection agreements has become more and more important among private ISPs both on regional and international levels. For instance, a group of ISPs in Kenya built internet exchange points (IXP) domestically in November, 2002, for improving the quality of their services and reducing connectivity cost. The ISPs on Level 3 in U.S.A. and Colt Telecom in Britain made an agreement to share the investment cost for the network infrastructure. ¹

Under these circumstances, it has been an important topic whether and/or how the governments should intervene in the interconnection agreements among private ISPs. In the real world, the Federal Communications Commission (FCC) claimed that the government does not need to intervene in the interconnection agreements among private ISPs (Kende, 2000). ² In the joint investigation in 1998 of the proposed merger between WorldCom and MCI, the European Commission and the US Department of Justice feared that the merged entity would have incentives to degrade the quality of interconnection with the rest of the Internet. As a result, these providers were required to sell about half of their Internet assets before they were allowed to merge (Crémer, Rey and Tirole, 2000). In this case the governments clearly thought that they needed to regulate, in some way, the private ISPs’ decision on the quality of interconnection.

In the recent Economics literature, Crémer, Rey and Tirole (2000) show, in the duopoly model where the ISPs engage in the Cournot-type quantity competition, that an ISP with a larger installed base will have incentives to degrade the quality of interconnection, because it will be able to gain the competitive advantage over an ISP with a smaller installed base. Given that the quality of interconnection on the industry level is de facto determined at the level offered by the bigger ISPs, the quality of interconnection, in their view, will be lower than what would be socially desirable. On the contrary, it has been shown in the model of Foros and Hansen (2001), where vertically and horizontally

¹See OECD (2001) for other examples.
²The foreign (Asia-Pacific) ISPs strongly claim that it is unfair for them to be obliged to pay the connection fee to the US ISPs. The FCC concludes that it is not necessary to regulate the private ISPs in the same way as in the traditional case of telephone companies.
differentiated ISPs compete à la Hotelling, that the investment for interconnection quality will be higher than the socially optimal level. This is because the ISPs can reduce the competitive pressure by raising the interconnection quality. It is thus suggested from their paper, though they do not mention explicitly, that the government should impose the investment tax to the private ISPs.

Roson (2002) has recently pointed out that the primary determinant of the different outcomes between Crémer, Rey and Tirole paper and Foros and Hansen paper is the "market expansion effect", triggered by a quality enhancement; this effect is present in the former but absent in the latter. That is, when the interconnection quality improves, new subscribers will come into the network in the model of Crémer et al. where an aggregate demand function (sensitive to quality) is used, while the total number of subscribers is fixed in the model of Foros and Hansen. From this viewpoint, Roson claims that since the number of subscribers to Internet services is steadily increasing around the world, the model of Crémer et al. seems closer to reality. Furthermore, since the seminal work by Katz and Shapiro (1985), the competition among firms has been analyzed as the Cournot-type competition in the stylized models of the market with network externalities. Then it will be of fundamental importance to focus on the Cournot-type competition among ISPs.

This paper considers the optimal policy intervention into the interconnection agreement between two symmetric ISPs who engage in the Cournot-type competition in a network service market. As a starting point, we will show that the interconnection quality is lower than the socially optimal level (section 2 and 3). This result is the opposite to that in Foros and Hansen but is the same as suggested by Crémer, Rey and Tirole. The difference between our paper and theirs is that they emphasize the difference in the size of the ISPs’ installed base in the determination of the interconnection quality while the ISPs are totally symmetric in our paper. We can thereby show the role of the "market expansion effect" much more clearly than in Crémer, Rey and Tirole, elucidating the correctness of the Roson’s insight. That is, the interconnection quality is lower than the socially optimal level because the ISPs do not correctly recognize the effect of a quality enhancement that induces new customers to come into the network service market and

\[\text{This does not mean that the setting of Foros and Hansen paper is irrelevant. The vertical and horizontal differentiation addressed in it is certainly an important issue in the Internet, which Roson (2002) also mentions.}\]
thus increase the consumers’ surplus.

Based on this result, we will present two new results on the optimal intervention in the private interconnection agreement. First, in the case where the two symmetric ISPs compete in the domestic market, we will derive the optimal rate of investment subsidy for the interconnection quality and find that it depends positively on the strength of network externalities (section 4). Second, taking into account the situation in reality where foreign ISPs are connecting to the ISPs in the USA, we extend the model into the case where home and foreign ISPs compete in the home market (section 5). The optimal subsidy rate provided by the home government is higher in the case of international competition than in the case where two ISPs are domestic firms. Section 6 gives concluding remarks.

2 The Model

We will build a model of the competition and compatibility between two symmetric ISPs in the final good (network service) market with network externality. The final good supplied by ISPs is basically access to the Internet. Each ISP operates its own local network. In order to consider the government’s optimal policy as well as the private interconnection agreements between the private ISPs, we formulate a three-stage game. In the first stage, the government chooses the investment subsidy rate that can affect the quality of interconnection agreed upon by the ISPs. In the second stage, the two ISPs make interconnection agreements, choosing the quality of interconnection (degree of compatibility) $k$, where $k \leq k \leq k$ (see below). In the third stage, the two ISPs engage in the Cournot-type quantity competition in the final good market. Internet access is assumed to be homogeneous from the customers’ point of view.

2.1 Network Structure

The network structure is similar to that in Foros and Hansen (2001). For communication between own customers (on-net traffic), the ISPs are offering a quality guarantee of $k$. If there are no private interconnection agreements between the ISPs, the interconnection service is provided by an Internet Backbone Provider (IBP) which is operated by a non-profit organization. While the quality $k$ of off-net communication is offered through the public interconnection point by the IBP, private $ISP_1$ and $ISP_2$ can invest, based on
the interconnection agreement, in a direct interconnection point (without the IBP) and thereby provide their customers with the quality $k$ of interconnection, where $\underline{k} \leq k \leq \overline{k}$.
For simplicity, the highest possible quality $\overline{k}$ is assumed to be 1.

2.2 Consumers

The ISPs are going to supply network service to consumers after making interconnection agreements. Consumers can purchase the network service by connecting to either ISP. We assume that each consumer purchases at most one unit of network service for one period (each consumer will not connect to both ISPs at the same time). The fixed advantage $x$ of being connected to the network varies across consumers and is assumed to be uniformly distributed over $[0, 1]$. ⁴ The consumer of type $x \in [0, 1]$ obtains, from subscribing to $ISP_i$ ($i=1,2$) who offers the price $p_i$ (connection fee), the net surplus equal to

$$x + s_i - p_i$$

where $s_i$ represents a positive externality that the consumer enjoys from connecting to $ISP_i$’s network. We assume that the network externality is linear in the expected network size

$$s_i = \beta(n_i + kn_j), \quad i, j = 1, 2; \quad i \neq j$$

(1)

where $n_i$ is the number of consumers connecting to $ISP_i$, $n_j$ the number of consumers connecting to the rival $ISP_j$. When the quality of interconnection $k \in [\underline{k}, 1]$ is higher, the expected network size $(n_i + kn_j)$ will be larger for the same levels of $n_i$ and $n_j$. In other words, $k$ measures the degree of compatibility between the two ISPs’ networks. On the other hand, parameter $\beta$ reflects the strength of network externality. Given the network size, a higher $\beta$ leads to a larger $s_i$. Consumers are assumed to be homogeneous in their valuations of the network externality ($\beta$). We assume $0 < \beta < \frac{1}{2}$ for the existence of a unique and stable Nash equilibrium. ⁵

The consumer of type $x$ connects to $ISP_i$ to maximize his or her net utility. If net utility is negative $(x + s_i - p_i < 0)$, then consumers of type $x$ don’t purchase any network

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⁴We normalize the total population of consumers to 1.

⁵The linear network externality function of an individual subscriber is used in, e.g., Crémer, Rey and Tirole (2000) and Daitoh and Yanagawa (1994). This is consistent with the Metcalfe’s law, which states that the aggregate network value is proportional to the square of network size. See Swann (2002) for detailed discussion of the functional form of network effects.
service from ISP\textsubscript{i}. Given the homogeneity of the network service, both ISPs will have a 
positive sale only if
\begin{equation}
p_i - s_i = p_j - s_j = \hat{p}, \quad i, j = 1, 2; \; i \neq j
\end{equation}
where \(p_i - s_i\) is the adjusted price from which the effect of network externality is excluded, 
that is, the price that the ISP\textsubscript{i} offers only for the fixed advantage \(x\) of the network service. 
If these adjusted prices are different, all consumers will intend to connect to the ISP who 
offers a lower price than the other ISP. Because the network service is homogeneous aside 
from the network externality, the demand for ISP\textsubscript{i} with a higher price will be zero. If 
both ISPs are to have positive sales, the adjusted prices must be equal between them.

If each ISP offers the price satisfying (2), only consumers of type \(x\) with \(x \geq p_i - s_i\) 
subscribe to ISP\textsubscript{i}. Given the uniform distribution of \(x\), the total demand is \(1 - \hat{p}\). Since 
the total supply of two ISPs is \(n_i + n_j\), we obtain
\begin{equation}
n_i + n_j = 1 - \hat{p}, \quad i, j = 1, 2; \; i \neq j
\end{equation}
From (1),(2) and (3), the prices \(p_i\) are determined by
\begin{align*}
p_i &= 1 - (n_i + n_j) + s_i \\
&= 1 - (1 - \beta)n_i - (1 - \beta k)n_j, \quad i, j = 1, 2; \; i \neq j
\end{align*}
This can be interpreted as the inverse demand curve that ISP\textsubscript{i} faces.

2.3 ISPs’ Behavior and Market Equilibrium

We assume that ISP\textsubscript{i} incurs a constant marginal (connectivity) cost \(c\) for supplying net-
work service to customers. In addition, they incur the investment cost \(I(k)\) for attaining 
the interconnection quality \(k\).\textsuperscript{6} Given the interconnection quality \(k\) in the second stage, 
ISP\textsubscript{i} chooses \(n_i\) so as to maximize its gross profit (excluding \(I(k)\))
\begin{align*}
\pi_i &= (p_i - c)n_i \\
&= \{1 - (1 - \beta)n_i - (1 - \beta k)n_j - c\}n_i \quad i, j = 1, 2; \; i \neq j
\end{align*}

\textsuperscript{6}The marginal cost \(c\) is almost zero while the fixed cost \(I(k)\) is large. This characteristic of the cost 
structure has been emphasized in, e.g. Harris (1995).
where he regards the rival ISP’s quantity \( n_j \) as given. The first-order condition (FOC) for profit maximization yields its reaction curve

\[
n_i = \frac{1 - c}{2(1 - \beta)} - \frac{1 - \beta k}{2(1 - \beta)} n_j, \quad i, j = 1, 2; \ i \neq j
\]  

(5)

Under the assumption of \( 0 < \beta < \frac{1}{2} \), the reaction curves of ISP\(_1\) and ISP\(_2\) are downward-sloping lines \( AB \) and \( CD \), respectively, in Figure 1. Therefore there uniquely exists a stable symmetric Nash equilibrium \( E \).

Using (5), the equilibrium outputs in the symmetric Nash equilibrium are

\[
n_i^* = \frac{1 - c}{2(1 - \beta) + (1 - \beta k)}, \quad i = 1, 2
\]  

(6)

Substituting (6) into (4) and rearranging the terms, the equilibrium price is

\[
p_i^* = \frac{(1 - \beta)(1 + c) + (1 - \beta k)c}{2(1 - \beta) + (1 - \beta k)}, \quad i = 1, 2
\]  

(7)

From (6) and (7), the gross profit function is

\[
\pi_i^* = \frac{(1 - \beta)(1 - c)^2}{\{2(1 - \beta) + (1 - \beta k)\}^2}, \quad i = 1, 2
\]  

(8)

When \( \beta \) becomes higher and/or the marginal cost \( c \) becomes lower, \( n_i^* \) increases and \( p_i^* \) declines. The strength of network externality increases, the demand from the consumers increases under the same output levels. Thus both ISPs expand the equilibrium output levels \( n_1^* \) and \( n_2^* \), and therefore, the total output increases and the price declines. On the other hand, a decline in the marginal cost leads to a rise in the gross profit of each ISP under the same price and output levels. Thus \( n_1^* \) and \( n_2^* \) increase and therefore the equilibrium price will decline.

### 3 Interconnection Quality

Now we will consider the second stage where the ISPs make a private interconnection agreement. In order to examine how the interconnection quality is determined, suppose that \( k \) improves. First, how will each ISP’s gross profit be affected? Differentiating the profit function (8) with respect to \( k \) yields

\[
\frac{\partial \pi_i^*}{\partial k} = \frac{2\beta(1 - \beta)(1 - c)^2}{\{2(1 - \beta) + (1 - \beta k)\}^3} > 0, \quad i = 1, 2
\]  

(9)
Because a rise in the interconnection quality leads to the same amount of increase in the profits between them, the two ISPs have the incentive to agree upon the same level of interconnection quality $k$.

To explain the reason for (9), we will show how the equilibrium price and quantities in the third stage will be affected by changing interconnection quality $k$. Differentiating (6) and (7) with respect to $k$, respectively, we get

$$
\frac{\partial n_i^*}{\partial k} = \frac{\beta(1-c)}{\{2(1-\beta) + (1-\beta k)\}^2}, \quad i = 1, 2
$$

(10)

$$
\frac{\partial p_i^*}{\partial k} = \frac{\beta(1-\beta)(1-c)}{\{2(1-\beta) + (1-\beta k)\}^2}, \quad i = 1, 2
$$

(11)

Following Foros and Hansen (2001), (10) and (11) represent the market share and price effects. In Foros and Hansen’s model of the differentiated ISPs, the price effect is positive, while the market share effect is positive for the inferior ISP but negative for the superior ISP. In our model, both effects are positive. First, (4) implies that given $n_j$, the demand for $n_i$ will be higher with the price $p_i$ fixed. This is because the value of the network for any individual consumer increases. Then, in Figure 1, the reaction curves of ISP$_1$ and ISP$_2$, i.e., AB and CD, shift outward to A'B and CD', respectively. The equilibrium outputs increase from $E$ to $E'$. Second, the quality enhancement increases the network size under the same output levels ($n_i$ and $n_j$). It means that the value of the network increases from the individual customer’s viewpoint, and thus they are willing to pay a higher price $p_i^*$.

Next, how will the consumers’ surplus change? From (4), we can calculate the consumers’ surplus:

$$
C(k) = \frac{1}{2}(n_i^* + n_j^*)^2, \quad i, j = 1, 2; \quad i \neq j
$$

$$
= \frac{2(1-c)^2}{\{2(1-\beta) + (1-\beta k)\}^2}
$$

(12)

Differentiating (12) with respect to $k$

$$
C'(k) = \frac{4\beta(1-c)^2}{\{2(1-\beta) + (1-\beta k)\}^3} > 0
$$

(13)

As $k$ rises, the consumers’ surplus increases.

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$^7$The consumers’ surplus depends on $k$, $\beta$ and $c$. For the purpose below, we will simply write it as $C(k)$. 

8
In order to increase the interconnection quality \( k \) above \( k \), the ISPs need to incur investment cost \( I = I(k) \), as mentioned above. \(^8\) One could argue that it is reasonable to expect the investment cost function to be convex. For example, the quality of interconnection is already high, an additional improvement in quality will become more difficult for technological reasons. Additionally, the contracts between the ISPs will probably become more complicated as the interconnection quality increases. We thus assume that \( I'(k) > 0 \) and \( I''(k) > 0 \) hold. For simplicity, it is also assumed that \( \lim_{k \to 1} I'(k) = \infty \) and \( \lim_{k \to k^*} I'(k) = 0 \).

Since the ISPs are symmetric, they will come to make an agreement in which they equally share the cost for investing in the interconnection quality. Thus we could assume that the ISPs form an input joint venture, as in Foros and Hansen. The government provides the ad valorem subsidy \( s \) for the joint venture’s investment in the interconnection quality, and each ISP will then maximize the net profit \( \pi_i - (1/2)(1-s)I(k) \). Thus the two ISPs will agree upon the interconnection quality \( k^d \) (the superscript "d" stands for "duopoly") characterized by

\[
k^d = \arg \max \{ \pi_i^*(k) - \frac{1}{2}(1-s)I(k) \}, \quad i = 1, 2
\]

Thus the interconnection quality is determined by the joint venture at the level where the marginal investment cost equals the marginal gross profit, \( (1/2)(1-s)I'(k) = \pi'_i(k) \). With (9), it will be convenient to write it as

\[
I'(k) = \frac{4\beta(1-\beta)(1-c)^2}{(1-s)(2(1-\beta) + (1-\beta k))^3}
\]

(14)

Under the assumptions above, as \( k \) comes closer to \( k \), \( (1/2)(1-s)I'(k) \) goes to zero. As \( k \) approaches to 1, \( (1/2)(1-s)I'(k) \) goes to infinity. On the other hand, the gross profit function is increasing and convex in \( k \). When \( k \) equals \( k \), \( \pi'(k) \) is larger than zero. When \( k \) equals unity, \( \pi'(1) \) takes a positive finite value. Therefore, \( \pi'(k) > (1/2)(1-s)I'(k) \) and \( \pi'(1) < (1/2)(1-s)I'(1) \) hold. Figure 2 illustrates these relations. Thus there uniquely exists a value of \( k \in (k, 1) \) satisfying (14).

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\(^8\)Assume that it is costless to improve the quality of interconnection. Then, since the profit function is equally increasing in \( k \), both ISPs will agree on the same quality level \( k = k^* = 1 \).
4 Optimal Investment Policy

Let us now consider the first stage where the government offers the investment subsidy rate so as to induce the ISPs to attain the socially optimal interconnection quality.

We will first derive the socially optimal level of interconnection quality \( k^* \). The socially optimal interconnection quality \( k^* \) is defined as the quality that maximizes the social welfare, which consists of the consumers’ surplus plus the total profits of both ISPs. The social welfare function is

\[
W(k) = \pi^*_i(k) + \pi^*_j(k) + C(k), \quad i, j = 1, \ 2; \ i \neq j
\]

\[
= \frac{2(2 - \beta)(1 - c)^2}{\{2(1 - \beta) + (1 - \beta k)\}^2}
\]

The socially optimal level \( k^* \) of interconnection quality is defined as

\[
k^* = \arg \max \{W(k) - I(k)\}
\]

Thus the government should set the investment subsidy rate \( s \) so as to induce the joint venture to choose the interconnection quality that satisfies

\[
I'(k) = \frac{4\beta(2 - \beta)(1 - c)^2}{\{2(1 - \beta) + (1 - \beta k)\}^3}
\]

where the RHS represents \( W'(k) \).

Comparing the equilibrium quality \( (k^d) \) characterized by (14) with the socially optimal quality \( (k^*) \) characterized by (15), we find that if \( s \) is zero, \( k^d < k^* \) holds, that is, the joint venture will choose the level of interconnection quality that is lower than the socially optimal level. Under the Cournot-type competition, the investment in the interconnection quality will be less than the socially optimal level.

Proposition 1 (Interconnection Quality) Suppose that two symmetric ISPs engage in the Cournot-type competition in the network service market and that the investment cost function for interconnection quality is increasing and convex. Then the interconnection quality determined in the private agreement between them is lower than the socially optimal level.

\footnote{We focus on the level of interconnection quality maximizing the social welfare under the assumption that the final good market keeps its duopoly structure. In this sense, the interconnection quality should be interpreted as, at most, "socially suboptimal". We will, however, use the term "socially optimal" with a slight abuse of terminology.}
Intuitively, this result of the less-than-optimal investment is due to the fact that the ISPs do not correctly recognize all the effects of a quality enhancement on the consumers’ surplus. There are two channels from the improvement in $k$ to the consumers’ surplus. First, a rise in $k$ increases the consumers’ willingness to pay because the network size $(n_i + kn_j)$ becomes larger with $n_i$ and $n_j$ fixed. Since the consumers will pay a higher price, the profit-maximizing ISPs can raise their prices and therefore take this effect into account. Second, when the quality of interconnection improves, new consumers get into the network and thus the number of customers ($n_i$ and $n_j$) increases. This is the ”market expansion effect”, which the ISPs don’t take into account from the individual viewpoint. Therefore the private incentive for investment to the interconnection quality will be lower than the social incentive. The ISPs will thus agree upon the quality of interconnection that is lower than the socially optimal level.

This result of the less-than-optimal interconnection quality is the same as suggested by Crémer, Rey and Tirole (2000) in which the ISP with a bigger installed base intends to gain the competitive advantage by degrading the interconnection quality and thereby differentiating his or her network service from that of the ISP with a smaller installed base. In our model, however, since the ISPs are symmetric, the ”market expansion effect” pointed out by Roson (2002), which is the primary determinant of the less-than-optimal quality of interconnection, can be shown much more clearly than in Crémer, Rey and Tirole (2000).¹⁰

In order to maximize the social welfare, the government should set the investment subsidy rate $s$ so that (14) should coincide with (15). Therefore, the optimal rate of investment subsidy is

$$s^* = \frac{1}{2 - \beta}$$

(16)

**Proposition 2 (Optimal Subsidy)** Suppose that two symmetric ISPs engage in the Cournot-type competition in the network service market and that the investment cost function for interconnection quality is increasing and convex. Then the government maximizing the social welfare should set the investment subsidy rate $s$ at the level given by (16).

¹⁰Katz and Shapiro (1985) pointed out that the private incentives for compatibility may be inadequate to achieve the socially optimal compatibility. However, they referred to the partial compatibility as the situation in which some out of all firms in the industry make their products compatible. Therefore, their finding is different from our result.
The optimal investment subsidy rate depends positively on the strength of the network externality (parameter $\beta$). If the network externality is stronger in the final good market, the government should set a higher investment subsidy rate in the private agreement between the ISPs. Roson (2002, p.79) conjectures that "intervention would be necessary only in the presence of significant asymmetries between firms." Our result suggests that even if the ISPs are symmetric, policy intervention into private interconnection agreements will be necessary from the social point of view.

5 Extension to International Competition

We will extend the basic model into the one for international competition between the home and foreign ISPs. Let us regard $ISP_1$ and $ISP_2$ as Home and Foreign ISPs, respectively. They compete à la Cournot in the domestic market of the home country. We assume that the home government subsidizes the private interconnection agreement to attain the investment level for interconnection quality that is socially optimal for the home country. Then, given the subsidy rate arbitrarily, the Nash equilibrium output levels in the third stage and the interconnection quality agreed upon in the second stage are the same as those in the basic model (i.e., (6) and (14)).

Let us consider the first stage where the government offers the investment subsidy rate $s_H$ so as to induce the ISPs to attain the socially optimal interconnection quality. The socially optimal interconnection quality $k^*_H$ is defined as the quality that maximizes the social welfare of home country, which consists of the home consumers’ surplus plus Home ISP’s profit. Thus the social welfare function is

$$W_H(k) = \pi^*_H(k) + C(k), \quad i, j = 1, 2; \ i \neq j$$

$$= \frac{(3 - \beta)(1 - c)^2}{(2 - \beta) + (1 - \beta k)}$$

The socially optimal level of interconnection quality is defined as

$$k^*_H = \arg \max \{W_H(k) - \frac{1}{2}I(k)\}$$

\[11\] It does not matter in this model whether the government gives the entire subsidy to Home ISP directly or provides the subsidy separately to each of Home and Foreign ISPs. Even if the entire subsidy is given to Home ISP, it will be equally shared between them in the agreement. Otherwise, the agreement would not be made.
Since the investment cost $I(k)$ is shared equally between the two ISPs, only a half of it needs to be incorporated into the welfare of the home country. Thus the government should set the investment subsidy rate $s_H$ so as to induce the interconnection quality that satisfies

$$I'(k) = \frac{4\beta(3 - \beta)(1 - c)^2}{2(1 - \beta) + (1 - \beta k)} \quad (17)$$

where the RHS represents $W'_H(k)$.

Comparing the equilibrium quality ($k^d$) characterized by (14) with the socially optimal quality ($k^*_H$) characterized by (17), we find that $k^d < k^*_H$ holds if $s$ is zero, that is, the joint venture will choose the quality of interconnection that is lower than the socially optimal level. Under the international competition, the investment in the interconnection quality will be lower than the socially optimal level.

**Proposition 3 (Interconnection Quality under International Competition)** Suppose that the symmetric home and foreign ISPs engage in the Cournot-type competition in the home market and that the investment cost function for interconnection quality is increasing and convex. Then the interconnection quality determined in the private agreement between them is lower than the socially optimal level for the home country.

The reason for the less-than-optimal investment is the same as that in the basic model of domestic competition. The ISPs don’t take into account the fact that when the quality of interconnection improves, new consumers get into the network and thus the consumers’ surplus increases.

In order to maximize the social welfare of the home country, the home government should set the investment subsidy rate $s_H$ so that (14) should coincide with (17). Therefore, the optimal rate of investment subsidy is

$$s^*_H = \frac{2}{3 - \beta} \quad (18)$$

**Proposition 4 (Optimal Subsidy under International Competition)** Suppose that the symmetric home and foreign ISPs engage in the Cournot-type competition in the home market and that the investment cost function for interconnection quality is increasing and convex. Then the home government maximizing the social welfare of the home country should set the investment subsidy rate $s_H$ at the level given by (18).
Comparing the optimal rates of investment subsidy between the domestic and international competition, one can easily find that the optimal subsidy rate is higher in the case of international competition than in the case of domestic competition. This is because the socially optimal investment level for interconnection quality is higher in the former case than in the latter case ($k_H^* > k^*$). Under the international competition, a half of the investment cost $I(k)$ is incurred by Foreign ISP through the private interconnection agreement. Then the half of $I(k)$ is eliminated from the social welfare of the home country, and thus the socially optimal investment level will be higher under the international competition. However, the investment level agreed upon in the private interconnection agreement is the same between the cases of domestic and international competition. Therefore, the incentive for the investment needs to be enhanced by a larger extent under the international competition, and thus the optimal investment subsidy rate is higher in the case of international competition than in the case of domestic competition.

6 Concluding Remarks

This paper has considered the optimal policy intervention into the private interconnection agreement between two symmetric ISPs competing \textit{à la} Cournot in a network service market. As a starting point, we showed that in contrast to Foros and Hansen (2002), the interconnection quality is lower than the socially optimal level. Although this result itself is the same as suggested by Crémer, Rey and Tirole (2000), we could show much more clearly the crucial role of the "market expansion effect" in making the private incentive for better quality of interconnection smaller than the social incentive, elucidating the correctness of the Roson (2002)'s insight. That is, the interconnection quality is lower than the socially optimal level because the ISPs do not correctly recognize the effect of a quality enhancement that induces new customers to get into the network service market and thus increase the consumers' surplus. Based on this result, we have presented two new results on the optimal intervention in the private interconnection agreement. First, in the case where the two symmetric domestic ISPs compete in the domestic market, the optimal rate of investment subsidy for the interconnection quality has been explicitly derived and it has turned out to be positively dependent on the strength of network externalities. Second, taking into account the situation in reality where foreign ISPs are
connecting to the ISPs in the USA, we have extended the model into the case where home and foreign ISPs compete in the home market. The optimal subsidy rate provided by the home government is higher in the case of international competition than in the case where two ISPs are domestic firms.

Let us mention three qualifications of this paper. First, we have utilized the linear network externality function. If it were a non-linear function, there could be multiple equilibria, as in Katz and Shapiro (1985). Then consumers’ expectations will play an important role in selecting the actual equilibrium. Second, we only focus on the two symmetric ISPs. If they were not symmetric (e.g., the marginal costs were different), we would have to discuss how the interconnection agreement would be made. One possibility would be the side payment, as in Katz and Shapiro. The other would be that it will be made by the bargaining between the ISPs, as was discussed in Crémer, Rey and Tirole (2000). We could also think of the situation where more than two ISPs are operating in the Internet service industry. Then it would be an interesting problem to consider how the market configuration (including monopoly) would be determined. Finally, the first-best social optimum should ultimately be attained by eliminating the distortion due to the strategic interdependence (duopoly) in the final good market. The role of competition policy will have to be discussed. These problem are left for future research.
References


