Revenue-Sharing and Interconnection in the Wireless Internet

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January 14, 2004

Abstract

We provide a framework within which the wireless Internet market can be analyzed both in the case of nonstandardization and in the case of standardization. Mainly, we obtain two results on regulation. First, we show that the choice of a revenue-sharing ratio between a network operator (NO) and a content provider (CP) has no real effect on prices, market shares nor social welfare in the case of nonstandardization. This implies that the ratio cannot be used as a policy variable. Second, we demonstrate that, in the case of standardization, the collusive interconnection charge is lower than the socially optimal level as far as the population mass of CPs is less dense than the population of Internet users.

Key Word: wireless Internet, revenue-sharing, interconnection, platform

JEL classification: D11

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1 Introduction

While the rapid growth in the number of users of cellular phones seems to reach its peak, it is expected that the number of wireless Internet users, together with that of various contents provided in the wireless Internet service, will grow very fast in the near future. According to the OVUM (2001)'s forecast, the number of mobile connections worldwide will grow from almost 727 million at the beginning of 2001 to more than 1,764 million by the beginning of 2005. Also, the number of mobile e-commerce subscribers will grow from a small base in 2001 to over 415 million by 2005. These subscribers are expected to generate mobile e-commerce revenues of more than $230 billion in 2005. ARC Group (2000) also forecasts that the rate of subscribers to the mobile Internet in developed countries such as U.S., Japan, Western European countries will amount to 70-80 % in 2005.

As the wireless Internet market becomes larger and more important, the regulatory body of each country needs efficient policies to promote the industry up to its potential and to fully take advantage of the synergy effect that is anticipated by the maturation of the market. It is indeed that voluminous theories on the voice communication market and the wired Internet market can provide a useful guideline for the purpose. Despite the apparent similarities, however, the wireless Internet service is, in nature, quite different from both the voice communication and the wired Internet service.

While voice communication is made between two final consumers in both directions, most of data communication is made from a content provider to a consumer in only one direction. Network operators (NOs) in the wireless Internet service play the role of not only mediating transmitting requested data from content providers (CPs) to consumers but also collecting the charges for using information goods from consumers for CPs. In practice, network operators reap revenues from both consumers and content providers in returns for mediating information transmission between them. So, their revenues consist of airtime charge[1] to consumers and some ratio of information usage fee[2] which consumers pay to CPs

[1]There are two kinds of wireless Internet pricing, so-called, circuit pricing whereby users are charged based on their length of usage time and packet pricing whereby users are charged based on the amount of information received. Although some countries such as Japan and Korea recently introduced packet pricing, circuit pricing is still a dominant form of pricing. See Kim, Lee and Kim (2001) for discussion of outcomes under circuit pricing and under packet pricing.

[2]The ratio that network operators grab is usually about 10%.

in return for using information goods they provide.

The wireless Internet service has something in common with the wired Internet service in that most of the communication over the wired Internet is unilateral from a (noncommercial) website to a consumer,[3] but the one is distinguished from the other in that, in the case of the wireless Internet service, NOs use their own nonstandardized platforms so that content providers must develop their contents, depending on specific platforms of a NO they want to be affiliated with, while, in the case of the wired Internet service, all NOs use the standardized platform. Although the issue of standardization in wireless Internet platforms recently has been actively discussed in international forums, it seems to be the case that it will take a fairly long time to have one and the same standard in practice in the wireless Internet as in the wired Internet.[4]

In this paper, we provide a framework within which the wireless Internet market is analyzed both in the case of nonstandardization and in the case of standardization. First, we consider a situation where there are two network operators providing uninteroperable services in the wireless Internet market.[5] Due to incompatibility between platforms each NO adopts, consumers subscribing to a network using a certain platform cannot receive information goods provided by CPs using the other platform. Therefore, a consumer's decision to choose

[3]In fact, the wireless Internet has exactly the same topology as the wired Internet. The wired Internet service is offered through vertically interwoven supply chains of various networks owned by several types of providers. The local incumbent, or generally speaking, a NO, offers Internet access service to customers via copper local loops and/or local switches, connecting user interface, such as PC, with the Internet owned by Internet service providers (ISP). ISPs manage customer service and provide CPs with connections to the Internet. In the case of the wireless Internet service market, NOs happen to be the only ISPs (at least in Korea).

[4]In Korea, there had been several platform standards, SK-VM and GVM (by SK Telecom), MAP, BREW (by KTF) and EZ-JAVA (by LGT) but, in July 2, 2002, the unified standard in the wireless Internet platform called WIPI (Wireless Internet Platform for Interoperability) was announced. However, handset manufacturers complain over this standardization policy by arguing that standardization in the wireless Internet platform will increase the number of platforms rather than reduce it. In fact, three major Korean network operators, SKT, KTF, LGT began to provide both services based on WIPI and their old platforms. For global concerns about the standardization of the wireless Internet service, see Kammer (2000).

[5]If mobile handsets with different platforms are not compatible with one another or contents written by different languages are not properly converted, physical interconnection does not guarantee the open system in the wireless Internet service market. Moreover, NOs themselves hesitate to open their networks to ISPs partly because the wireless Internet service market is on a rudimentary stage so that it is beneficial to fully take advantage of the installed base of their own customers.

a network he will join in is affected by the number of CPs in each network and, likewise, a CP's affiliation decision is affected by the number of subscribers in each network. Of course, a CP may provide its service in both networks by producing two versions of its product using different platforms (multihoming), but high development costs usually prevents financially constrained CPs from doing so. On this ground, the wireless Internet market involves indirect network externalities.

Subsequently, we consider a situation in which two NOs in the wireless Internet market adopt the standardized platform, so that a consumer in one network can use information of CPs in the other network. In this case, interoperability enables both consumers and CPs not to care about the network size of each NO. In other words, network externalities disappear.[6] However, interconnection between networks emerges as a new issue.[7]

In this paper, we are interested in the market outcome and possible policies to enhance efficiency in the wirelss Internet market. Unlike in the case of voice communication, content providers play a crucial role in the wireless Internet industry. The attractiveness of a network is determined by how many, how wide and how good contents the network holds. Also, it appears that the ratio dividing revenues between a NO and a CP affects the number of CPs in the network and the quality of CPs as well.[8] However, this turns out not to be the case.

We obtain two results. First, we show that the choice of a revenue-sharing ratio has no real effect on prices, market shares nor social welfare in the case of nonstandardization. This implies that the ratio cannot be used as a policy variable. Second, we demonstrate that, in the case of standardization, the collusive interconnection charge is even lower than the socially optimal level (which is below the access cost within a reasonably wide range

[6] We mean "individual" network externalities. "Overall" network externalities are still present even in the case of standardization in the sense that consumers want to subscribe to a network more as there are more CPs in the market and CPs have a stronger incentive to enter the market as there are more subscribers in the market. Similarly, in the case of voice communication in which networks are clearly interoperational, network extenalities are not present, unless firms engage in price discrimination between on-net communication and off-net communication.

[7] In the case of the wired Internet, there are currently two types of interconnection, peering and transit. Peering, which is the "bill and keep" arrangement, is usually used between ISPs with similar network sizes, while ISPs in different hierarchies usually enter into a transit agreement since the volumes of communication between them are asymmetric.

[8] Cheong (2001) argues that, in the case of monopoly, a NO has an incentive to set too high a revenue-sharing ratio, resulting in low-quality information goods being produced.

of parameters) as far as the population mass of CPs is less dense than the population of Internet users. This result is in a sharp contrast with the case of voice communication. As Laffont *et at.* (1998a) show, in the case of telecommunications, the collusive access charge is determined at a level above the access cost, whereas Ramsey access charge is below the access cost.

Rochet and Tirole (2001) provide a more general model in which network externalities are two-sided. Their analysis also contains both cases of compatibility and no compatibility between platforms, but is distinguished from ours in the sense that the access charge is determined by not-for-profit associations.

As a more closely related work, Laffont *et al.* (2001) also offer a framework for the Internet market. However, our view on the Internet market is somewhat different from them. Basically, they view information providers (websites) as consumers who are not paid but pay for providing information, whereas we regard content providers as sellers paid for it. Our view is relatively relevant to the wireless Internet industry where contents are usually not free,[9] while their view is more compatible with the wired Internet industry. Moreover, considering a recent trend towards non-free contents in the wired Internet service, we believe that our framework will become more relevant to the wired Internet market as well.

2 The Model[10]

We consider two competing network operators $i = 1, 2$ and a continuum of consumers and content providers contemplating joining in one of the networks. Consumers buy data provided by CPs through networks. NOs mediate transmitting information from CPs to consumers and are paid for the mediation. A NO's revenues consist of the price for using its network plus a certain share of the information usage fee determined by CPs. The share of the usage fee divided between a NO and a CP is exogenously given.[11] The NO collects the usage fee from consumers instead of CPs and keeps the share of the revenues in return for mediation, giving out the rest of the revenues to CPs. A consumer who joins in network i can

[9] In Korea, contents in the wireless Internet has been charged for since April, 2001.

[10] This model is adapted from Kang and Kim (2001) which is an extension of Katz and Shapiro (1985) to the case of indirect network externalities.

[11] This may be due to regulation or *ex ante* agreement between the NO and the delegate of CPs.

have access only to CPs affiliated with the network, that is, two networks are not compatible with each other. We assume that two networks are homogeneous except for compatibility.

There is no quality difference among contents provided by CPs. We assume that all consumers demand only one unit of data from each content provider affiliated with their network i.e., have inelastic demand. This assumption will be relaxed in Section 4.

The cost of transmitting the unit packet consists of the originating cost and the terminating cost, and is assumed to be constant. Also, we assume that the fixed cost incurred to a NO for serving a subscriber is negligible and that the entry cost of a NO is sunk. No cost is incurred to CPs in providing information.[12]

We use the following notation all throughout the paper.

x_i = network size of consumers joining in network i
y_i = network size of CPs joining in network i
x_i^e = CPs' expectations on x_i
y_i^e = consumers' expectations on y_i
p_i = price of NO i for transmitting a unit data
$\tilde{p}_i$ = price of CP joining in network i for using a unit data
α = NOs' common share of the revenue
π_i = profit of NO i
c_o = the originating cost
c_t = the terminating cost
c = total cost where $c = c_o + c_t$
v = a consumer's gross valuation for the unit data
m = a consumer's stand-alone valuation for joining in a network[13]
δ = development cost of a CP

The issue of interconnection between networks will not be addressed until Section 5 dealing with the compatibility case in which off-net communication is possible.

A consumer can join in either one or no network. Let the utility of a consumer joining in

[12] The cost of providing information may be positive, but this assumption reflects the reality that it is quite small relative to the cost of transmitting information.

[13] We are implicitly assuming that a consumer derives some utility simply from subscribing to the wireless Internet service without consuming non-free data. Just imagine a situation where there are some free data provided by the NO itself.

a network consists of a stand-alone component and a network component. The stand-alone component is independent of the network size of CPs, while the network component is. Let the utility of a subscriber to network i be $U_i(r_i, y_i^e) \equiv m + y_i^e(v - r_i)$, where $r_i = p_i + \tilde{p}_i$ is the effective price for the Internet service by NO i. As long as $v > r_i$, he will request data from each CP in network i. In that sense, a consumer is benefited more from joining in a network with the larger network size of CPs. We assume that m is uniformly distributed over $(-\infty, \overline{m}]$ with density one.[14] We will call m the type of a consumer.

CPs also join in at most one network. Denoting by V_i the profit of a CP joining in network i, we can write V_i as $x_i^e(1-\alpha)\tilde{p}_i - \delta$. This says that it is more profitable to a CP when it joins in a network with more subscribers. Again, we assume that δ, the type of a CP, is uniformly distributed over $[\underline{c}, \infty)$ with density $\mu > 0$.

3 Analysis

A consumer of type m chooses network $i = \arg\max_i U_i(r_i, y_i^e)$. If $U_i(r_i, y_i^e) < 0$ for all i, an m-type consumer joins in neither network. Similarly, a CP of type δ chooses network i maximizing $V_i(\alpha, \tilde{p}_i, x_i^e)$. If $V_i(\alpha, \tilde{p}_i, x_i^e) < 0$ for all i, a δ-type CP joins in neither network.

Given the homogeneity of the networks, two NOs will both have the positive number of subscribers only if

$$y_1^e(v - r_1) = y_2^e(v - r_2), \tag{1}$$

where y_i^e is the net valuation from joining network i, augmented by the network size. Equation (1) says that the network-augmented net valuations must be equal when both NOs have positive sales. Since only those consumers for whom $m \geq y_i^e(r_i - v)$ enter the Internet market, the size of such consumers is $\overline{m} + y_i^e(v - r_i)$, given the uniform distribution of m. Thus, the following must be satisfied

$$\overline{m} + y_i^e(v - r_i) = x_1 + x_2, \tag{2}$$

for $i = 1, 2$, or equivalently,

$$r_i = v - \frac{x_1 + x_2 - \overline{m}}{y_i^e}. \tag{3}$$

[14]The assumption of no lower bound for m is to avoid the corner solution.

This is the inverse demand function for the Internet service, implying that the total demand for the Internet service depends on the effective price, r_i, and the expected network size of CPs compatible with it, y_i^e.

Let us compute the consumer surplus. The surplus of type m consumer is $m+y_i^e(v-r_i) = x_1+x_2-(\overline{m}-m)$. Since only consumers whose stand-alone utility is greater than $\overline{m}-x_1-x_2$ join in a network, the total consumer surplus is $S = \int_{\overline{m}-x_1-x_2}^{\overline{m}}(x_1+x_2-\overline{m}+m)dm = \frac{1}{2}x^2$, where $x \equiv x_1+x_2$. In other words, consumer surplus increases exponentially with a grow in the number of Internet users.

Similarly, two NOs will both have the positive number of CPs only if

$$x_1^e \tilde{p}_1 = x_2^e \tilde{p}_2. \tag{4}$$

Equation (4) says that a CP's expected profits from joining in either network must be equal when both NOs have positive number of CPs.

Since only those CPs for whom $\delta \leq x_i^e(1-\alpha)\tilde{p}_i$ i.e., the development cost does not exceed its virtual net supply price (adjusted for its customer network size) enter the market, it follows from the assumption of the uniform distribution of δ that the mass of such CPs is $\mu[x_i^e(1-\alpha)\tilde{p}_i - \underline{c}]$. This implies that the following must be satisfied

$$\mu[x_i^e(1-\alpha)\tilde{p}_i - \underline{c}] = y_1 + y_2, \tag{5}$$

for $i = 1, 2$. From equation (5), it follows that

$$(1-\alpha)\tilde{p}_i = \frac{(y_1+y_2)/\mu + \underline{c}}{x_i^e}. \tag{6}$$

This is the inverse supply function of CPs. It says that the total number of CPs in the market depends on the revenue a CP gets from providing a unit information and the expected network size of consumers affiliated with its network, x_i^e. Thus, a CP's profit is $x_i^e(1-\alpha)\tilde{p}_i - \delta = (y_1+y_2)/\mu + \underline{c} - \delta$ and the CPs' total profit is $T = \int_{\underline{c}}^{\underline{c}+z}(z+\underline{c}-\delta)d\delta = \frac{1}{2}z^2$, where $z = y/\mu = (y_1+y_2)/\mu$. This says that the total profit in the CP industry rises exponentially with an increase in the number of CPs in the market.

Now, let us consider the decisions of NOs. The profit of NO i is given as

$$\begin{aligned} \pi_i &= x_i y_i (p_i + \alpha\tilde{p}_i - c) \\ &= x_i y_i [r_i - (1-\alpha)\tilde{p}_i - c]. \end{aligned} \tag{7}$$

The interpretation of (7) is that the revenue accruing to a NO when a subscriber gets access to a CP affiliated with it is the subscriber's total payment minus the CP's revenue.

From equation (3) and (6), equation (7) can be rewritten as

$$\pi_i = x_i y_i [v - c - \frac{x - \overline{m}}{y_i^e} - \frac{z + \underline{c}}{x_i^e}]. \tag{8}$$

The first order conditions require that

$$\frac{\partial \pi_i}{\partial x_i} = y_i [v - c - \frac{x - \overline{m}}{y_i^e} - \frac{z + \underline{c}}{x_i^e} - \frac{x_i}{y_i^e}] = 0. \tag{9}$$

$$\frac{\partial \pi_i}{\partial y_i} = x_i [v - c - \frac{x - \overline{m}}{y_i^e} - \frac{z + \underline{c}}{x_i^e} - \frac{y_i}{\mu x_i^e}] = 0. \tag{10}$$

Equation (9) says that the direct increase in the revenue following an incremental change in the number of subscriber must be equal to the indirect decrease in the revenue due to a drop in the effective price. Economic reasoning behind equation (10) is a little bit more complicated. Serving an addition CP has consequences on p_i and $\tilde{p}_i$ in conflicting directions. First, $\tilde{p}_i$ must rise for an increase in the supply of CPs. However, p_i must fall in the same proportion as $\tilde{p}_i$ in order to maintain the effective price, r_i, as same, which is required for holding x_i as constant. Thus, the net price effect of an increase in y_i is negative. Equation (10) says that the direct effect of serving an additional CP on the revenue must be offset by this negative price effect.

It is equivalent to writing (9) and (10) as follows,

$$\frac{\rho_i - c}{\rho_i} = \eta_{x_i} = \eta_{y_i}, \tag{11}$$

where $\rho_i = v - \frac{x - \overline{m}}{y_i^e} - \frac{z + \underline{c}}{x_i^e}$ is the total price NO i charges to both consumers and CPs for delivering a unit of information, and $\eta_{x_i} = -\frac{\partial \rho_i}{\partial x_i}\frac{x_i}{\rho_i}$ and $\eta_{y_i} = -\frac{\partial \rho_i}{\partial y_i}\frac{y_i}{\rho_i}$. This is the standard Lerner formula.

Now, equilibrium network sizes, x_i^* and y_i^*, depend on how consumers and CPs form their expectations on the size of each network. According to Katz and Shapiro (1985), we will assume that all expectations are actually fulfilled, i.e., $x_i^e = x_i^*$, $y_i^e = y_i^*$. Then, since $\partial \rho_i / \partial x_i = -\frac{1}{y_i^e}$ and $\partial \rho_i / \partial y_i = -\frac{1}{\mu x_i^e}$, equation (11) implies that $y_i^* = \sqrt{\mu} x_i^*$. In a symmetric equilibrium,[15] we have

$$x_i^* = \frac{\overline{m}/\sqrt{\mu} - \underline{c}}{5/\sqrt{\mu} - v + c}.$$

[15] Here, a symmetric equilibrium implies that NOs in the same situation choose the same amount.

It is easy to check that the second order condition is satisfied at this optimum. Notice that neither x_i^* nor y_i^* does not depend on α.

As a result, equilibrium prices associated with the symmetric equilibrium are given by

$$(1-\alpha)\tilde{p}^* = \frac{2}{\sqrt{\mu}} + \frac{\underline{c}}{\overline{m}/\sqrt{\mu} - \underline{c}}(5/\sqrt{\mu} - v + c),$$

$$r^* = v - \frac{1}{\sqrt{\mu}}\left[2 - \frac{\overline{m}}{\overline{m}/\sqrt{\mu} - \underline{c}}(5/\sqrt{\mu} - v + c)\right].$$

Also, it is easy to see that the equilibrium profit is $\pi_i^* = (x_i^*)^2 = \frac{1}{\mu}(y_i^*)^2$. It is noteworthy that a CP's supply price, $\tilde{p}^*$, depends on the transmission cost of a NO, c. As c becomes higher, NOs would like to reduce the number of subscribers to each network, in turn decreasing the number of CPs, which work jointly as two forces to push r^* and $\tilde{p}^*$ upward.

Meanwhile, the social welfare can be defined by

$$W = \Pi + S + T,$$

where $\Pi = \sum_{i=1}^2 \pi_i$. It follows from straightforward calculations that

$$W = \sum_{i=1}^{2}(x_i^*)^2 + \frac{1}{2}(x^*)^2 + \frac{1}{2}(z^*)^2 = (1 + \frac{1}{2\mu})(x^*)^2. \tag{12}$$

We are now in a position to see the effects of a change in α. Main results are summarized by the following two propositions.

Proposition 1 *(i) $\tilde{p}^*$ is strictly increasing in α. (ii) p^* is strictly decreasing in α. (iii) r^* is constant with a change in α.*

Proof. Trivial

As the share of NOs becomes larger (α becomes higher), each NO wants to host more CPs. Hence, a rise in the price of CPs. Similarly, with an increase in the (per subscriber) revenue due to a higher α, each NO prefers more subscribers. As a result, p^* must fall.

Proposition 2 (Independence Result) *None of consumers' surplus, CPs' profits nor NOs' profits depend on α. Consequently, the social welfare is independent of α.*

A change in α has no real effect at all due to concomitant countervailing changes in p^* and $\tilde{p}^*$. This result suggests that the level of the revenue-sharing ratio does not matter from the social point of view nor from NOs' point of view whether the revenue-sharing ratio is regulated or set by the agreement between a NO and a CP, or to what level it is determined. The intuitive reason for this result is as follows. In this model, the revenue that NO i reaps when a subscriber gets access to a CP is the total price a consumer pays (which depends entirely on the total number of subscribers) minus a CP's revenue (which is determined in the market by the total number of CPs). In particular, the latter, $(1-\alpha)\tilde{p}_i$ is invariant with respect to a change in α because if a subsequent change in $\tilde{p}_i$ as long as x_i and y_i are given.

This result has an interesting policy implication. It tells us that, because all changes in α are reflected in p^* and $\tilde{p}^*$, the government does not have to intervene in the process of determination of α. Therefore, the government's policy to influence the NO's share of the information usage fee downwards for inducing a wider variety of contents could not help to attract more CPs.

4 Discussion on the Independence Result

The independence result is quite robust to various modifications of the basic model set up in the previous section. In this section, I will discuss the robustness in the case of two major modifications.

Elastic Demand

Suppose that consumers have the elastic demand for information goods, so that, after joining in a network, they can choose the amount of data transmitted, q_i from a CP in the network so as to

$$\max_{q_i} u(q_i) - r_i q_i,$$

where $u' > 0$ and $u'' < 0$.

The first-order condition requires that

$$u'(q_i^*) = r_i,$$

implying that $q_i^* = D(r_i)$, where $D(r_i) \equiv u'^{-1}(r_i)$. Notice that $D' < 0$ from $u'' < 0$.

For simplicity, we will assume that a consumer requests the same amount of information from each CP in his network.[16] Let $U_i = m + y_i^e v(r_i)$, where $v(r_i) = u(D(r_i)) - r_i D(r_i)$. Then, equation (1) and (2) are replaced by

$$y_1^e v(r_1) = y_2^e v(r_2), \tag{13}$$

$$\overline{m} + y_i^e v(r_i) = x_1 + x_2. \tag{14}$$

From (14), we obtain

$$r_i = \gamma(\frac{x_1 + x_2 - \overline{m}}{y_i^e}), \tag{15}$$

where $\gamma = v^{-1}$, as the counterpart for equation (3).

Similarly, the counterpart for equation (6) is

$$(1-\alpha)\tilde{p}_i q_i^* = \frac{(y_1 + y_2)/\mu + \underline{c}}{x_i^e}. \tag{16}$$

Therefore, NO i's profit is given by

$$\begin{aligned} \pi_i &= x_i y_i [r_i - (1-\alpha)\tilde{p}_i - c] q_i^* \\ &= x_i y_i \left[\left(\gamma(\frac{x_1 + x_2 - \overline{m}}{y_i^e}) - c \right) D(\gamma(\frac{x_1 + x_2 - \overline{m}}{y_i^e})) - \frac{(y_1 + y_2)/\mu + \underline{c}}{x_i^e} \right]. \end{aligned} \tag{17}$$

We can easily see that π_i does not involve α, implying that the independence result still holds.

Proposition 3 *The independence result holds even in the case of the elastic demand.*

This robustness result is due to another fact that a consumer's demand for information goods depends on the effective price, r_i, which is determined independently of α.

[16] This assumption, called the uniform (or balanced) calling pattern, has been used by many authors including Artle and Averous (1973), Squire (1973), Rohlfs (1974), Laffont et al. (1998a, b) and Armstrong (1998) in the context of voice communication. The implication of this assumption is that no one has any special interest. Although it is true that most people have some specific area of interest, it seems fair to say that this assumption is at least a reasonable approximation of reality.

Fixed Fee for Delivering Information Goods

Suppose that NOs collect a lump-sum amount, τ, for mediating information instead of a ratio proportional to the unit price of contents.

In this case, equation (3) describing the determination of the effective price for the service remains unaffected, but equation (5) describing the net supply price of contents is changed to

$$\tilde{p}_i = \tau + \frac{(y_1 + y_2)/\mu + \underline{c}}{x_i^e}. \tag{18}$$

Also, NO i's profit is

$$\pi_i = x_i y_i (p_i + \tau - c) = x_i y_i [r_i - \frac{(y_1 + y_2)/\mu + \underline{c}}{x_i^e} - c]$$

by using (18). Since r_i does not depend on τ given x_i and y_i as seen in (3), it is clear that the independence result still holds.

Proposition 4 *The independence result holds even in the case of the lump-sum transfer for information mediation.*

5 Standardization in Network Platforms

In this section, we consider an alternative case in which two networks achieve compatibility by adopting standardized platforms so that a subscriber to a network can use contents provided by the other network.

In this case, if a consumer in network i requests data from a CP in network $j (\neq i)$, NO i will first collect p_i plus $\tilde{p}_j$ per packet and then return $\tilde{p}_j$ and pay an originating fee a to NO j as an interconnection charge.[17] Then, NO j will keep the interconnection charge plus $\alpha\tilde{p}_j$ and give $(1 - \alpha)\tilde{p}_j$ to the CP from which the consumer has requested data.

We will preserve assumptions on the cost structure, i.e., the originating cost and the terminating cost are constant, c_o and c_t respectively, whether data transmission is inbound or outbound.

Since a consumer joining in either network gets the same network benefits, he will join in the network whose price is lower, which leads to $p_1 = p_2$ for the positive mass of both

[17] Laffont *et al.* (2001) assume alternatively that the originating party (i.e. the NO sending data) pays an interconnection charge as a terminating fee.

network users. We will denote the common price by p^s. On the other hand, since any CP joining in either network can get the same network benefit, it will charge the same price, which will be denoted by $\tilde{p}^s$.

Since a consumer joins in a network only when $m+(y_1^e+y_2^e)(v-r^s)\geq 0$, it must be that

$$\overline{m}+(y_1^e+y_2^e)(v-r^s)=x_1+x_2, \tag{19}$$

where $r^s=p^s+\tilde{p}^s$. Similarly, a CP joins in a network only when $\delta\leq(x_1^e+x_2^e)(1-\alpha)\tilde{p}^s$, implying that

$$\mu[(x_1^e+x_2^e)(1-\alpha)\tilde{p}^s-\underline{c}]=y_1+y_2. \tag{20}$$

Thus, a consumer's surplus in this case is $m+(y_1^e+y_2^e)(v-r^s)=x_1+x_2-\overline{m}+m$. So, the total surplus is $S=\int_{\overline{m}-x_1-x_2}^{\overline{m}}(x_1+x_2-\overline{m}+m)dm=\frac{1}{2}x^2$ just as in the case of nonstandardization. Similarly, the total surplus of CPs is $T=\frac{1}{2}z^2$.

Now, the profit of NO i is

$$\pi_i=x_iy_i(p_i+\alpha\tilde{p}_i-c)+x_iy_j(p_i-c_t-a)+x_jy_i(\alpha\tilde{p}_i-c_o+a). \tag{21}$$

The first term (the second term, *resp.*) is the profit of NO i from its subscribers who get access to CPs in network i (network j *resp.*) and the last term is its profit accruing from the other network's subscribers requesting data from CPs in network i.

From (19) and (20), we have

$$r^s=v-\frac{x-\overline{m}}{y_1^e+y_2^e}, \tag{22}$$

$$\tilde{p}^s=\frac{1}{1-\alpha}\frac{z+\underline{c}}{x_1^e+x_2^e}. \tag{23}$$

Equation (22) is the inverse demand function for the Internet service and equation (23) is the inverse supply function of contents in the case of standardization. From equation (22) and (23), we get

$$p^s=v-\frac{x-\overline{m}}{y_1^e+y_2^e}-\frac{1}{1-\alpha}\frac{z+\underline{c}}{x_1^e+x_2^e}. \tag{24}$$

Thus,

$$p^s+\alpha\tilde{p}^s=v-\frac{x-\overline{m}}{y_1^e+y_2^e}-\frac{z+\underline{c}}{x_1^e+x_2^e}. \tag{25}$$

This says that NO i's revenue from on-net communication does not depend on α, given x_i and y_i. However, the revenue from off-net communication does depend on α. So, it is clear that the independence result does not hold, if two networks become compatible and it enables subscribers to one network to use information from the other network.

Using (22), (23) and (24), the first order conditions require that

$$\begin{aligned}\frac{\partial \pi_i}{\partial x_i} &= (y_1+y_2)[v-\frac{x_1+x_2-\overline{m}}{y_1^e+y_2^e}-\frac{(y_1+y_2)/\mu+\underline{c}}{x_1^e+x_2^e}-\frac{x_i}{y_1^e+y_2^e}-c] \\ &\quad -y_j[\frac{\alpha}{1-\alpha}\frac{(y_1+y_2)/\mu+\underline{c}}{x_1^e+x_2^e}+a-c_o]=0. \qquad (26)\\ \frac{\partial \pi_i}{\partial y_i} &= x_i[v-\frac{x_1+x_2-\overline{m}}{y_1^e+y_2^e}-\frac{(y_1+y_2)/\mu+\underline{c}}{x_1^e+x_2^e}-c-\frac{y_i}{\mu(x_1^e+x_2^e)}] \\ &\quad +x_j[\frac{\alpha}{1-\alpha}\frac{(y_1+y_2)/\mu+\underline{c}}{x_1^e+x_2^e}-c_o+a+\frac{1}{\mu}\frac{\alpha}{1-\alpha}\frac{y_i}{x_1^e+x_2^e}] \\ &\quad -\frac{x_iy_j}{\mu}\frac{1}{1-\alpha}\frac{1}{x_1^e+x_2^e}=0. \qquad (27)\end{aligned}$$

Let the solutions satisfying (26) and (27) be x_i^{**} and y_i^{**}, $i=1,2$ and let $x^{**}\equiv x_1^{**}+x_2^{**}$ and $y^{**}\equiv y_1^{**}+y_2^{**}$. Then, in a symmetric equilibrium, (26) and (27) are reduced to

$$y^{**}\left[v-\frac{x^{**}-\overline{m}}{y^{**}}-\frac{y^{**}/\mu+\underline{c}}{x^{**}}-c\right]-\frac{y^{**}}{2}\left[\frac{\alpha}{1-\alpha}\frac{y^{**}/\mu+\underline{c}}{x^{**}}+a-c_o\right]-\frac{x^{**}}{2}=0, \qquad (28)$$

$$x^{**}\left[v-\frac{x^{**}-\overline{m}}{y^{**}}-\frac{y^{**}/\mu+\underline{c}}{x^{**}}-c\right]+x^{**}\left[\frac{\alpha}{1-\alpha}\frac{y^{**}/\mu+\underline{c}}{x^{**}}+a-c_o\right]-y^{**}/\mu=0,\text{[18]} \qquad (29)$$

where $x^{**}\equiv x_1^{**}+x_2^{**}$.

Equation (28) has the usual interpretation that a direct increase in the NO's revenue from both on-net communications and off-net communications by serving an additional subscriber must be equal to an indirect decrease in its profit due to a fall in the unit price for serving a subscriber. The first two terms indicate the direct revenue increase, while the third term, $-x^{**}/2$, is the effect of a price fall. Equation (29) can be similarly interpreted.

[18] Apart from the market power due to quantity competition, there is no reason for the off-net-cost pricing principle suggested by Laffont *et al.* (2001) to hold in this model. It holds in their model because the opportunity cost of serving a customer is the opportunity cost of stealing him away from its rival and both are equal to the off-net-cost. However, this is the case only when the total demand for networks is inelastic. Since the network demand is elastic in our model, the opportunity cost of serving a customer is not equal to that of stealing him from the other's network. So, prices must depend both on the off-net-cost (c_o-a) and the on-net-cost (c_o+c_t).

Since $\frac{\partial^2 \pi_i}{\partial x_i^2} = -2$ and $\frac{\partial^2 \pi_i}{\partial y_i^2} = \frac{2\alpha - 1}{\mu(1-\alpha)}$, the second order condition is satisfied if $[\frac{\partial^2 \pi_i}{\partial x_i \partial y_i}]^2 < \frac{2(1-2\alpha)}{\mu(1-\alpha)}$. Notice that a necessary condition for satisfying the second order condition is that $\alpha < \frac{1}{2}$.

Equation (28) and (29) say that equilibrium network sizes, x_i^{**} and y_i^{**}, are affected by the size of interconnection charge as well as the revenue-sharing ratio in the case of standardization. In fact, the size of interconnection charge plays a crucial role in determining the market size of wireless Internet service in this case. Intuitively, an increase in the interconnection charge decreases the number of subscribers and increases the number of CPs directly because more subscribers would make an NO pay higher interconnection charges to the other NO and more CPs would make it earn higher revenues. However, an increase in the interconnection charge also has a mutual indirect effect on x_i^{**} (y_i^{**}, *resp.*) through a change in y_i^{**} (x_i^{**}, *resp.*). So, the overall effect of a on x_i^{**} and y_i^{**} is ambiguous. A change in α has an effect similar to a change in a. As its share in the information usage fee rises, an NO would like to host more CPs and less consumers. But, the indirect effect makes its total effect on x_i^{**} and y_i^{**} ambiguous.

Now, the sum of the profits of two NOs is

$$\Pi = 4x_i^{**}y_i^{**}(p + \alpha\tilde{p} - c) = x^{**}y^{**}[v - \frac{x^{**} - \overline{m}}{y^{**}} - \frac{y^{**}/\mu + \underline{c}}{x^{**}} - c]. \quad (30)$$

Therefore, the social welfare is given by

$$W = \Pi + S + T = (v - c)x^{**}y^{**} - x^{**}(x^{**} - \overline{m}) - y^{**}(y^{**}/\mu + \underline{c}) + \frac{1}{2}x^{**2} + \frac{1}{2}z^{**2}. \quad (31)$$

Combining (28) and (29), we get

$$\Pi = \frac{1}{3}(x^{**2} + y^{**2}/\mu), \quad (32)$$

$$W = \frac{1}{3}(x^{**2} + y^{**2}/\mu) + \frac{1}{2}(x^{**2} + y^{**2}/\mu^2). \quad (33)$$

This implies that the social optimum does not, in general, coincide with the private optimum unless $\mu = 1$. If $\mu = 1$, colluding NOs will always choose the socially optimal level of a and α.

Proposition 5 *If $\mu = 1$, the private optimum of colluding NOs coincides with the social optimum. Otherwise, the private optimum and the social optimum do not coincide in general.*

Also, comparison between (12) and (33) leads to the following proposition.

Proposition 6 *The social welfare is increased if network platforms are standardized, as long as* $x_i^{**} > x_i^*$ *and* $y_i^{**} > y_i^*$, $i = 1, 2$.

It is true that standardization does not guarantee larger network sizes, because the actual realization of network sizes critically depend on expectations of consumers and CPs. However, if they reasonably expect that networks will be enlarged after standardization, the social welfare will be clearly increased.

Below, we present a numerical exercise to illustrate the equilibrium network sizes, the optimal values of a and α, and the relationships among them, since the equilibrium network sizes, x^{**} and y^{**}, described by Equations (28) and (29) take a form of a nonlinear equation system which does not produce an explicit analytical solution. As a benchmark, we consider the case that $\mu = 1$ and set the parameter values of $v - c = 2$, $\overline{m} = 5$, $\underline{c} = 2$, $\alpha = 0.1$, and $a - c_0 = 0$. The benchmark case produces the equilibrium values of the network sizes, $x^{**} = 5.746$ and $y^{**} = 4.65$, which are far greater than the optimal values of the incompatible case, $x^* = y^* = 1$ given the parameter values. This confirms the possibility of welfare improvement with standardization of the network over the incompatibility case, which is discussed in Proposition 6.

We also examine the effects of changes in some parameter values on the equilibrium values of the network sizes and the welfare (or equivalently the profits of the network operators) given $\mu = 1$. Figure 1 shows how the welfare is affected by the change in the share of the network providers' revenue (α) with all the other parameters unchanged. As the share increases starting from zero, the welfare (profits) is slightly higher reaching the maximum at 0.028 before it declines after it. It shows that there is an optimal value of the share maximizing the profits if it is a choice variable. Figure 2 draws the changes in the equilibrium network sizes x^{**} and y^{**} with a change in the network operators' revenue share. The higher the value of the revenue share of the network operators, the smaller the number of the network subscribers while the higher the number of CPs. The higher NOs' revenue share lowers p^s, but raises $\alpha\tilde{p}^s$, which makes it to the advantage of NOs to have less subscribers and more CPs.

Figures 3 and 4 show the effects of a change in the interconnection charge (α is back to the benchmark value, 0.1). Since the parameters a and c_0 always go together in the form of $a - c_0$ in the first order conditions (28) and (29), the effect of an increase in the interconnection charge is equivalent to a decrease in the originating cost. Figure 3 shows that there is an optimal value of the interconnection charge maximizing the profits (-0.087 here implying a smaller interconnection charge than the originating cost). This confirms the intuition of Laffont *et al.* (1998a) that the social optimum requires NOs' market power to be offset by a positive subsidy of the access input. Figure 4 illustrates the effect of a change in the interconnection charge on equilibrium network sizes. As put in p. 16, a higher interconnection charge directly decreases the number of a NO's subscribers and increases the number of CPs but there is also the indirect synergy effect, which makes the net effect ambiguous. The numerical exercise shows the indirect synergy effect dominates the direct effect in the most of the region except the proximity of the optimum.

Figures 5 and 6 illustrate the case that $\mu < 1$. As shown in Figure 5, the peak for y^{**} must be on the right side of the peak of x^{**} because otherwise x^{**} could be increasing in $a - c_0$ while y^{**} were decreasing, which would not be possible. This implies that the collusive interconnection charge is even lower than the socially optimal level as illustrated in Figure 6. This discrepancy between the private incentive and the social incentive is aggravated when μ is smaller. If $\mu = 1$, the social optimum is attained when $x^2 + y^2$ is maximized, just as the private optimum of colluding NOs is, since the society would care equally about CPs as well as consumers. However, if $\mu < 1$, the colluding NOs care less about y than the society. To implement the lower level of y than the socially optimal level, the colluding NOs will set their interconnection charge below the socially optimal level. The same argument can be applied to the relation between the collusive revenue-sharing ratio and the socially optimal ratio. Since a change in α affects x^{**} and y^{**} in the same direction as a change in a does, the collusive ration tends to be lower than the socially optimal one, unless changes in x^{**} and y^{**} are monotone in α. This suggests that it may be better for the government to have a policy to encourage a higher revenue-sharing ratio rather than a lower ratio.

Proposition 7 *When $\mu < 1$, the collusive interconnection charge is lower than the socially optimal level.*

Proof. The formal proof is direct from (32), (33) and the observation that $\partial^2 \pi_i / (\partial x_i \partial a) < 0$ and $\partial^2 \pi_i / (\partial y_i \partial a) > 0$ from (26) and (27).

6 Conclusion

In this paper, we provided a framework within which the wireless Internet market is analyzed and obtained two main results; (i) the revenue-sharing ratio has no real effect in the case of nonstandardization and (ii) the collusive interconnection charge is lower than the socially optimal level in the case of standardization, as far as the population mass of CPs is less dense than the population of Internet users. Extending this basic model into various directions will be left as future projects.

Acknowledgment: This research was begun while the first author was visiting the University at Albany, SUNY. He is grateful to Michael Jerison, Michael Sattinger, Kwan Yun for their hospitality during the stay and Insuk Cheong for inspiring this project. We also thank audiences at the Telecommunications Policy Workshop sponsored by the Korea Association for Telecommunications Policies for helpful comments and Korea Information Society Development Institute (KISDI) for financial support.

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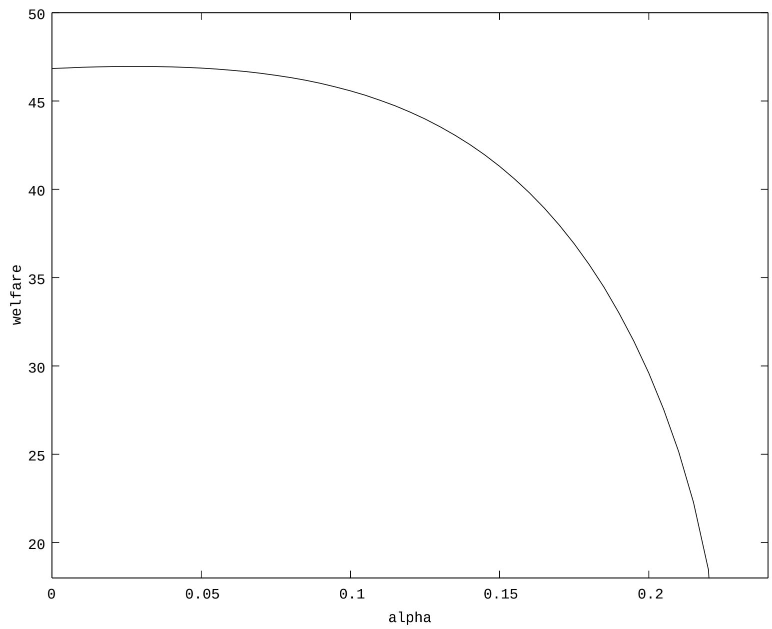

Figure 1: Social Welfare and Network Operators' Revenue Share

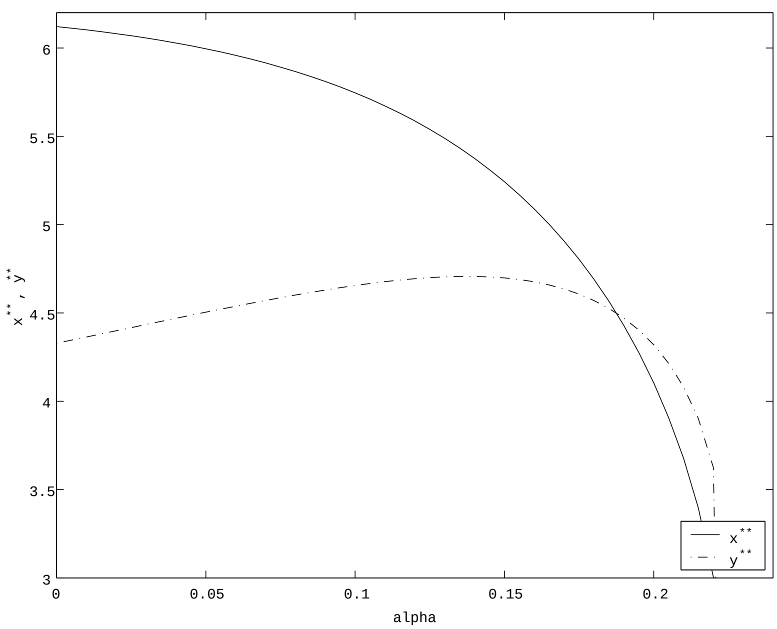

Figure 2: Effect of Changes in α on x^{**} and y^{**}

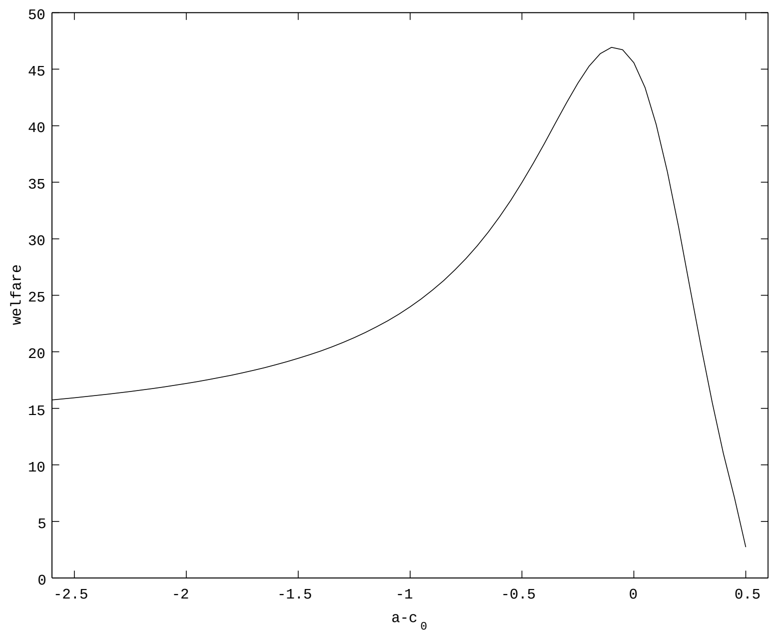

Figure 3: Social Welfare and Interconnection Charge minus Originating Cost

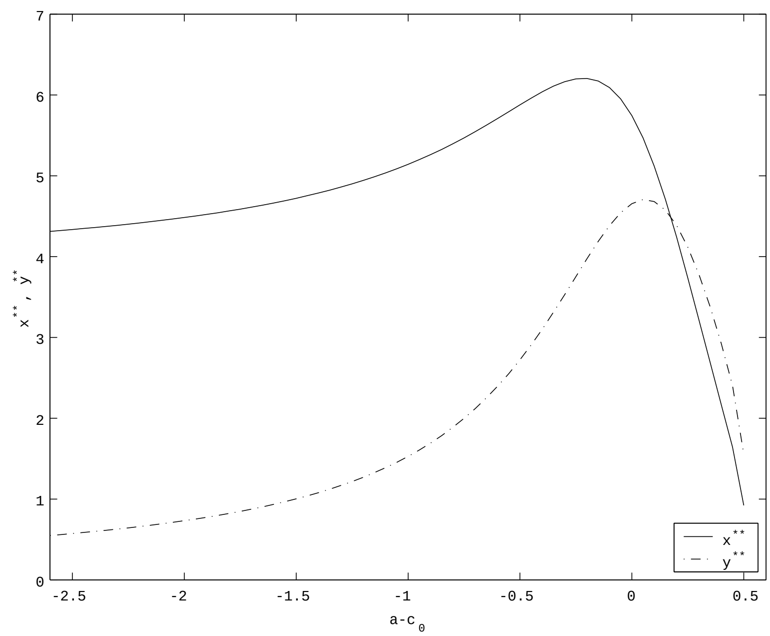

Figure 4: Effect of Changes in $a - c_0$ on x^{**} and y^{**}

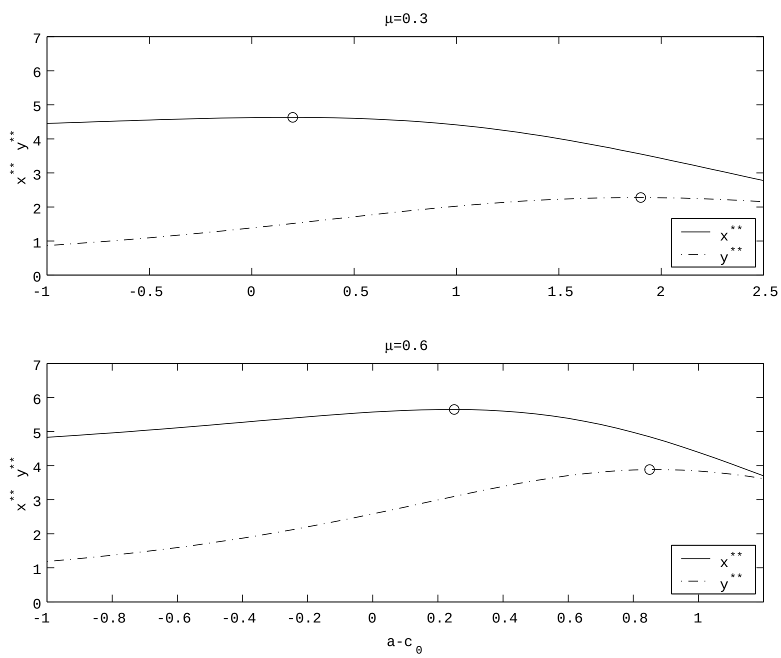

Figure 5: x^{**} and y^{**} with a change in $a - c_0$ for a value of μ

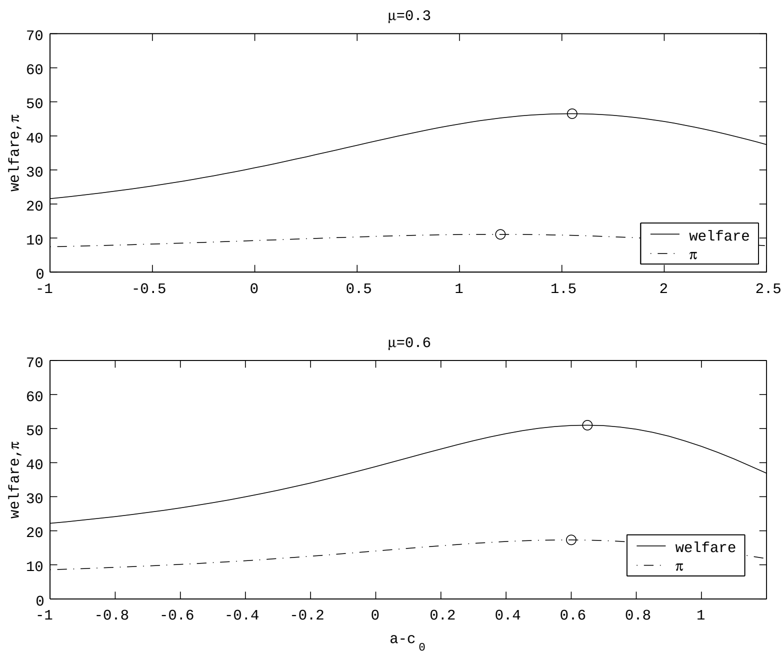

Figure 6: Social Welfare and Π with a change in $a - c_0$ for a value of μ