An Economic Analysis of the Receiver Pays Principle

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January 16, 2000

Abstract

This paper is to examine the effect of the receiver pays principle (RPP) on the calling price, social welfare and interconnection charge. We demonstrate that the calling price under RPP must be lower than the price under the caller pays principle (CPP), that the profit of a firm will be increased under RPP, but that the consumer surplus will not necessarily be increased under RPP despite the lowered calling price. Also, we show that, if the demand function is linear, the reciprocal interconnection charge under RPP is higher than that under CPP.

Journal of Economic Literature Classification Code: L10

Key Words: receiver pays principle, caller pays principle, reciprocal interconnection charge

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1 Introduction

The most striking characteristics of the telecommunications industry that are distinguished from other industries might be the presence of two kinds of externalities, network externalities and call extermalities. Network externalities result from the fact that a subscriber to a network is made better off by being able to communicate with more people if more people subscribe to the network. Call externalities occur since both the calling party and the receiving party may benefit from a phone call, even though the cost usually falls entirely on the caller. Therefore, call externalities are the product of a particular usage fee payment system, so-called the caller pays principle (CPP) that the caller only is charged for a call, while network externalites are a characteristic inherent in the telecommunications industry.

Then, why do most countries adopt CPP in spite of the obvious free-riding of the receiving parties?[1] The traditional rationale for this apparent unfairness is that, even if the receiver is bound to bear a part of the calling charge, the reduced amount of fees for a person in calling and the additional amount of fees to bear in receiving are almost averaged out, if the calling ratio and the receiving ratio are similar, so that CPP is as good as the receiver pays principle (RPP) that the receiving party is charged in part for a call as well.[2] Furthermore, if we take

[1]Recently, the use of RPP is observed in some restricted situations. In particular, the U.S. and some other countries (e.g. Hong Kong) adopt RPP in mobile call pricing. However, it is well-known that this is for a technological reason, rather than for an economic reason. Since mobile service providers do not have distinct network access codes, a consumer cannot tell whether the call he is making terminates on the fixed network or on the mobile network. Therefore, it may be considered unfair to charge the high price of the mobile phone call to a consumer who does not realize to which network he is calling. Collect call services and toll-free, 800-number services are other examples for RPP.

[2]To implement RPP requires telecommunications service carriers to release freely information for their customers upon request by another carrier, and this is ensured by the U.S. Telecommunications Act of 1996. It provides "each $\cdots$ local exchange carrier has the duty to provide, to any requesting telecommunications carrier for the provision of a telecommunications service, nondiscriminatory access to network elements on an unbundled basis $\cdots$. An $\cdots$ local exchange carrier shall provide such unbundled network elements in a manner that allows requesting carriers to combine such elements in order to provide such telecommunications service." (the Telecommunications Act of 1996, section 251, c3.) In addition, it provides "A telecommunications carrier that receives or obtains proprietary information from another carrier for purposes of providing any telecommunications service shall use such information only for such purpose, and shall not use such information for its own marketing efforts." (the Telecommunications Act of 1996, section 702, b.)

into account technical difficulties and administrational costs involved with collecting charges from the receivers as well, it seems that there is no reason to use RPP instead of CPP.[3] However, in fact, this is true only in a restricted sense. First of all, there currently coexist several networks interconnected to each other, say a PSTN and mobile networks, whose call traffic patterns are asymmetric.[4] In most countries, a large proportion of calls originating from a mobile network terminate on the PSTN and only a small proportion of calls made on the PSTN terminate on mobile networks. This implies that subscribers to mobile networks subsidize subscribers to the PSTN. This observation weakens the strong rationale that has justified CPP and makes us resort to an alternative fee system whereby the receiver pays for some of a phone call. Moreover, even in a situation where there is no mobile network, so that asymmetry in calling patterns is not significant, internalization of call externalities by dividing a calling charge between the caller and the receiver would lower the calling price, thereby increasing the quantity to be called, which would obviously affect social welfare.

It is of course that RPP is not the only way to internalize call externalities. Many informal mechanisms seem to have a similar effect. For instance, voluntary negotiations between calling parties may help internalize some of call externalities. (Coase (1960)) However, Acton and Vogelsang (1990) suspects that such voluntary negotiations are highly unlikely (especially for international calls) because negotiations that would lead to internalization themselves require phone calls. On the other hand, Littlechild (1977) points out that "friends who talk long distance regularly can agree to take turns." In other words, he regards call externalities as not substantial relative to network externalites since they can be easily internalized by cooperation between calling parties.[5] However, this argument is based on repeated relation between the parties. Since a large proportion of telephone communications

[3]CPP may be a historically established convention. In the past when only the manual or the mechanic switching system was feasible, it would have been technically impossible to implement RPP, and the resulting CPP would have been placed as a longstanding payment system.

[4]According to the Ovum report by Joseph and Nourouz (1996), only 33% of all mobile calls in U.S. are incoming. Doyle et al. (1998) also observe this asymmetric call patterns in the UK market. These observations imply that the balanced calling pattern assumption often used in literature is violated in reality.

[5]There may be other reasons why the literature has paid little attention to call externalities. First of all, it is hard to estimate the value of receiving a call. Also, most of the literature has been concentrated on the analysis of local calling where the (marginal) price is close to zero. See Acton and Vogelsang (1990).

are accidental, it is hard to expect enough internalization of call externalites by cooperation.[6]

In this paper, we examine the effect of RPP on the calling price, social welfare and the interconnection charge. A significant trouble with introducing this system in telecommunications pricing will be the possibility of nuisance calls that give negative utility to the receivers. However, this may not be a serious problem in a practical sense. Usually, a receiver can tell whether the call he is receiving is a nuisance or not within a very short time interval, such as 5 to 10 seconds. So, if the receiver is charged only after the lapse of 5 to 10 seconds from the instant he received the call, this problem will disappear (even if a small amount of losses to the firm are inevitable). Recently developed services such as selective call blocking, caller line identification or voice mail system will also serve to alleviate this problem. Another problem is the possibility that the receiving party may refuse to receive a call if the charge he has to bear is unreasonably high.[7] We find the condition for no calls to be refused and show that the profit maximizing prices charged to the calling party and the receiving party must satisfy this condition. Two models are provided in this paper. In a simple model with a single network, we demonstrate that the calling price under RPP must be lower than the price under CPP. Also, we find some interesting results that the profit of a firm will be increased under RPP but that the consumer surplus will not be necessarily increased under RPP despite the lowered calling price. However, it will also be shown that, if the demand for calls has a constant price elasticity, the consumer surplus will be unambiguously increased under RPP. In a general model with two networks, we derive some implications of the RPP system on the access pricing. In particular, it is shown that introducing RPP has a negative effect on the interconncetion charge in the sense that the reciprocal access charge is higher under RPP than under CPP.

[6]Also, Squire (1973) points out that marginal cost pricing is not efficient in the presence of call externalities and asserts that the price of calls should be below their marginal costs. This is correct of course, but it would not be economically feasible to implement such pricing, since the service provider would lose money unless someone else, say, the goverment makes up for the losses.

[7]Many U.S. mobile subscribers are not willing to give their mobile phone numbers to anyone but close friends and family because they pay for all the incoming calls they receive. In fact, the fact that all calls have to be paid for by the receiving party is viewed as a major barrier to high penetration of mobile phones into the U.S. market.

2 A Simple Model with A Single Network

There are one firm (or network) supplying telephony services and two representative subscribers, indexed by $i = 1, 2$, calling to each other.[8] We assume each call generates positive utility both for the caller and for the receiver.[9] If only the caller pays for a call, neither consumer has any reason to refuse to receive any call made to him as long as it yields positive utility. Thus, if consumer 1 makes q_1 calls to consumer 2 and consumer 2 makes q_2 calls to consumer 1, the number of calls consumer 1 (consumer 2) is willing to receive is the same as q_2 (q_1 respectively). Both consumers have the same preferences satisfying some regular properties. Denoting by $U^i(q_i, q_j)$ the utility function of consumer i for $j \neq i$, we make the following assumptions on $U^i(q_i, q_j)$.

Assumption 1 *$U^i(q_i, q_j)$ is additively separable i.e., $U^i(q_i, q_j) = u(q_i) + v(q_j)$, $j \neq i$, $i = 1, 2$.*

Assumption 2 *$v(\cdot) = \theta u(\cdot)$, for some $\theta \in (0, 1]$.*

Assumption 3 *$u(0) = 0$, $u'(\cdot) > 0$ and $u''(\cdot) < 0$.*

Assumption 1 makes the decision of each consumer independent to each other. Assumption 2 reflects the fact that willingness to pay for calling and for being called are usually no the same and that the person with the higher willingness to pay usually initiates a call. Assumption 3 implies that the call made and the call received are not perfect substitutes.[10]

The firm is assumed to incur a variable cost $c (> 0)$ per call. We assume that a fixed cost per subscriber is negligible and that the costs of building facilities are sunk.

[8] We are assuming implicitly that both consumers have joined the network. This is not a restrictive assumption because consumers who have joined the network have the option of making no calls and receiving no calls, so that they have no reason to hesitate to join the network unless they have to pay the subscription fee or the fixed fee per period. Also, even if they have to pay some fee irrespective of their usage, this assumption can be justified by the observation that the term of subscription contracts is often one year or longer. A similar spirit can be found in Economides et al. (1998).

[9] In reality, some calls may give negative utility to the receiver. These can be called nuisance calls. We ignore the possibility of nuisance calls in this article on the ground that the receiver can distinguish nuisance calls from calls yielding positive utility and discontinue the conversation himself in seconds.

[10] Imperfect substitutability comes from $u''(\cdot) < 0$. As a matter of fact, making calls incurs additional costs of looking for the numbers and dialing them both of which the receiving party can spare, while receiving calls incurs the extra costs of being abruptly interrupted, etc.

Decisions by the firm and the consumers are made sequentially; first, the firm sets its price schedule, and then, consumers choose the quantity of callings, q_1, q_2 simultaneously.[11] The firm may practice various pricing strategies, for example, two-part tariffs, price discrimination between two consumers etc. However, for expositional simplicity, we assume throughout that the firm uses uniform linear pricing under both the caller pays principle and the receiver pays principle.

A. Caller Pays Principle

If the firm charges p per call to the caller, the consumer i's net surplus from joining the network and consuming (q_1, q_2), denoted by V_i^C, is $U^i(q_i, q_j) - pq_i$. The first order condition implies that consumer i chooses q_i^* satisfying

$$\frac{\partial V_i^C}{\partial q_i} = u'(q_i^*) - p = 0, i = 1, 2 \tag{1}$$

By the implicit function theorem, we can write consumer i's demand q_i^* for making calls as a function of p i.e., $q_i^* = D(p)$ where $D'(p) < 0$.

Then, the firm chooses p^* solving

$$\max_p \pi^C(p) = (p - c)Q = 2(p - c)D(p), \tag{2}$$

where Q is the total quantity of callings. Assuming that the second order condition is satisfied, the profit-maximizing price, p^*, must satisfy

$$D(p^*) + (p^* - c)D'(p^*) = 0, \tag{3}$$

or in terms of elasticities,

$$p^* = \frac{\eta(p^*)}{\eta(p^*) - 1}c(> c), \tag{4}$$

where η is the price elasticity of demand, and $\frac{\eta}{\eta-1}$ is a markup factor.

[11] In this model, the firm's pricing decision has no effect on consumers' subscription decision at all. This feature of the model will be modified in section 3.

B. Receiver Pays Principle

Suppose that the firm charges $p_C(\geq 0)$ per call to the caller and $p_R(\geq 0)$ per call to the receiver. Then, one of the serious problems that one could expect to encounter would be the possibility that the receiver might refuse to receive a call if p_R were very high. In the following, we will first find the condition for the price vector (p_C, p_R) to prevent any call from being refused, solve for the profit-maximizing price vector under the constraint that the condition is satisfied, and show that any price vector violating the condition cannot be profit-maximizing.

Let $q_{i,C}(q_{i,R})$ denote the number of calls consumer i intends to make (receive respectively). He will solve

$$\max_{q_{i,C}, q_{i,R}} V_i^R = u(q_{i,C}) + v(q_{i,R}) - p_C q_{i,C} - p_R q_{i,R}$$

Let $q_{i,C}^*$, $q_{i,R}^*$, $i = 1, 2$ be the optimal solutions for this program. Then, first order conditions imply that

$$\frac{\partial V_i^R}{\partial q_{i,C}} = u'(q_{i,C}^*) - p_C = 0 \tag{5}$$

$$\frac{\partial V_i^R}{\partial q_{i,R}} = v'(q_{i,R}^*) - p_R = 0 \tag{6}$$

Meanwhile, in order for no call to be refused, it must be the case that $q_{i,C}^* \leq q_{j,R}^*$ and $q_{i,R}^* \geq q_{j,C}^*$, $j \neq i$. The first inequality implies that no call from consumer i is refused and the second inequaltiy implies that no call is refused by consumer i. From these inequalities, we can get a simple condition of no call refusal given by the following lemma.

Lemma 1 *No call is refused if and only if $p_R \leq \theta p_C$.*

Proof. $q_{i,C}^* \leq q_{j,R}^*$ and $q_{i,R}^* \leq q_{j,C}^*$ together with (5) and (6) are equivalent to $p_R \leq \theta p_C$, since $p_R \leq v'(q_{j,C}^*) = v'(u'^{-1}(p_C)) = \theta p_C$ and $\theta p_C \geq \theta u'(q_{j,R}^*) = \theta u'(v'^{-1}(p_R)) = \theta u'(u'^{-1}(\frac{p_R}{\theta})) = p_R$ from assumption 2 and 3.

If $p_R \leq \theta p_C$, all intended calls are actually realized. Thus, in that case, $q_{i,C}$ and $q_{i,R}$ can be used to denote the number of calls made and received respectively.

The firm's optimization problem with the constraint that no call be refused is then

$$\max_{p_C, p_R} \pi^R(p_C, p_R) = 2(p_C + p_R - c)D(p_C)$$

$$\text{subject to } p_R \le \theta p_C$$

We can see easily that the profit goes up unambiguously as p_R is increased up to θp_C. Thus, the optimal prices, p_C^*, p_R^* must make the constraint binding, yielding $p_R^* = \theta p_C^*$. This observation enables us to transform the constrained optimization program into

$$\max_{p_C} \tilde{\pi}^R(p_C) = 2\{(1+\theta)p_C - c\}D(p_C) \tag{7}$$

Assuming that the second order condition is satisfied, we have

$$D(p_C^*) + (p_C^* - \frac{c}{1+\theta})D'(p_C^*) = 0, \tag{8}$$

or in terms of elasticities,

$$p_C^* = \frac{1}{1+\theta}\frac{\eta(p_C^*)}{\eta(p_C^*) - 1}c. \tag{9}$$

At this point, some may wonder if the firm could do better by freeing itself from the constraint. However, the following lemma tells us that it is not possible, but that we can confine ourselves to the constrained optimization problem to search for the price vector maximizing its profit. Proposition 1 summarizes this.

Lemma 2 *The price vector violating the condition for no call refusal cannot be profit-maximizing.*

Proof. See the appendix.

Proposition 1 *The profit-maximizing price vector under RPP is* (p_C^*, p_R^*) *where* p_C^* *satisfies (8) and* $p_R^* = \theta p_C^*$.

C. Comparison

We are in position to compare the outcome under RPP with that under CPP. Several comparision results are in order.

Proposition 2 $p^* > p_C^* (\ge p_R^*)$.

Proof. It follows directly from equations (3) and (8) and the second order conditions of the optimization programs (2) and (7). (See figure 1.)

The intuition for proposition 2 is clear. Charging a price p_R to the receiver in addition to the caller is equivalent to lowering the unit cost by p_R. If the unit cost is lowered, a profit-maximizing firm would charge a lower price.

If we let the total quantity of calls to be supplied under CPP (under RPP respectively) be Q^C (Q^R), we have $Q^C = q_1^* + q_2^*$ and $Q^R = \sum_{i=1,2,j\neq i} \min\{q_{i,C}^*, q_{j,R}^*\} = q_{1,C}^* + q_{2,C}^*$. Then, the following corollary is a direct consequence of proposition 2.

Corollary 1 $Q^R > Q^C$.

The intuition behind corollary 1 is that, under RPP, consumers do not take $p_C + p_R$ into account in choosing the quantity of call-makings, but p_C only. p_R affects only the quantity of call-receivings, but the actual quantity of calls is totally determined by the quantity of call-makings, since, in equilibrium, p_R is so set that no calls may be refused.

Also, we have the following proposition.

Proposition 3 $p_C^* + p_R^* \geq p^*$ *if* $\eta'(p) \geq 0$ *for all* p.

Proof. $p_C^* + p_R^* = (1+\theta)p_C^* = \frac{\eta(p_C^*)}{\eta(p_C^*)-1}c \geq \frac{\eta(p^*)}{\eta(p^*)-1}c = p^*$ if $\eta'(p) \geq 0, \forall p$, since $p^* > p_C^*$ from proposition 2.

The intuitive reason why the ratio of p_C^* to p^* is related to the derivative of the elasticity of demand is as follows. Introducing RPP lowers the price the caller must pay per call. If the demand becomes less elastic as the price falls ($\eta'(p)$ is large), the profit-maximizing firm must charge a high p_C relative to the case that adopting RPP makes the demand more sensitive to price. In the meantime, it is not difficult to imagine a situation where $p_C^* + p_R^* < p^*$. For example, if we have a kinky demand curve,[12] so that it is very steep above some particular price level and becomes very flat below it, the firm will find it to its advantage to charge a very low calling price, since it can greatly increase the total quantity of callings.

Let $\hat{\pi}^C$, $\hat{\pi}^R$ be optimal values of the programs (2), (7) respectively. Then, we have

[12]A kinky demand curve, of course, involves non-differentiability at the kinked point. However, we can slightly modify it into a differentiable function by smoothing around the point.

Proposition 4 $\hat{\pi}^R > \hat{\pi}^C$.

Proof. This is obvious from the definitions of $\hat{\pi}^R$ and $\hat{\pi}^C$, since $\tilde{\pi}(p) > \pi(p)$ for all p.

The intuition for proposition 4 is that RPP shifts the demand curve outwards, which can be seen from $\tilde{\pi}(\tilde{p}) = (\tilde{p} - c)D(\frac{\tilde{p}}{1+\theta})$ where $\tilde{p} \equiv p_C + p_R$ is the total unit price under RPP. This result is, in fact, not surprising, considering that, under RPP, the firm could be at least as profitable as under CPP, since it always has the option of charging exactly the same price as it charges under CPP.

On the other hand, consumer surplus under two alternative fee systems can be computed as

$$\begin{aligned} CS^C &= \sum_{i=1,2,j\neq i} \{u(q_i^*) + v(q_j^*) - p^* q_i^*\} \\ &= \sum_{i=1}^{2} \{(1+\theta) \int_0^{q_i^*} D^{-1}(q_i) dq_i - p^* q_i^*\} \qquad (10) \\ CS^R &= \sum_{i=1}^{2} \{u(q_{i,C}^*) - p_C^* q_{i,C}^* + v(q_{i,R}^*) - p_R^* q_{i,R}^*\} \\ &= (1+\theta) \sum_{i=1}^{2} \{\int_0^{q_{i,C}^*} D^{-1}(q_i) dq_i - p_C^* q_{i,C}^*\}. \qquad (11) \end{aligned}$$

In words, the difference in consumer surplus between RPP and CPP is equal to the unambiguous increase in surplus due to the increased quantities of callings plus the change in surplus due to the total price consumers pay. Therefore, it is clear that RPP increases consumer surplus if it does not increase the total price i.e., $p_C^* + p_R^* \leq p^*$. Moreover, if it increases the total price but not very much, i.e., $p_C^* + p_R^* \approx p^*$, which is implied by $\eta(p_C^*) \approx \eta(p^*)$,[13] the effect of the increase in consumer surplus due to the increase in the volume of callings dominates the effect of the increase in surplus due to the higher total price, so that consumer surplus would be increased.

Figure 2 illustrates the case of $\theta = 1$. Denote the areas of regions A, B, C and D as α, β, γ and δ, respectively. Then, CS^C can be measured as $2\alpha + \beta + \delta$ and CS^R as the area of $2(\alpha + \beta + \gamma)$. Thus, the relative magnitude of consumer surplus under two systems

[13] This may occur when $\eta(p)$ is decreasing or increasing very slowly in p around p^*, or more fundamentally, if $D''(p)$ is very large at p^*.

depends on the relative size of δ and $\beta + 2\gamma$ and, in general, we cannot conclude that one is larger than the other. In particular, if p_C^* is quite close to p^* so that β and γ are very small, consumer surplus under RPP may be smaller than under CPP. Proposition 5 summarizes this intuition.

Proposition 5 *Consumer surplus under RPP is larger than consumer surplus under CPP, if $p^* \geq p_C^* + p_R^*$. However, it is not necessarily larger in general.*

Proof. See the appendix.

Example 1: Suppose $u(q) = -bq(q-2l)$ where $b > 0$, $l > 0$ and $q < l$. This utility function satisfies assumption 3, since $u'(q) = 2b(l-q) > 0$ and $u''(q) = -2b < 0$. From the consumers' problem, we have $q^* = D(p) = l - \frac{p}{2b}$, yielding $\eta'(p) = \frac{2bl}{(2bl-p)^2} > 0$. First order conditions of the firm's problem give $p^* = bl + \frac{c}{2}$ and $p_C^* = bl + \frac{c}{2(1+\theta)}$. Then, consumer surplus under CPP and under RPP can be computed as $CS^C = 2b(1+\theta)\{l^2 - \frac{1}{4}(l + \frac{c}{2b})^2\} - b\{l^2 - (\frac{c}{2b})^2\}$, $CS^R = 2b(1+\theta)[l^2 - \frac{1}{4}\{l + \frac{c}{2b(1+\theta)}\}^2] - b(1+\theta)[l^2 - \{\frac{c}{2b(1+\theta)}\}^2]$, so that $W \equiv CS^C - CS^R = \frac{b(1+\theta)}{2}[\{l + \frac{c}{2b(1+\theta)}\}^2 - (l + \frac{c}{2b})^2] + b(1+\theta)[l^2 - \{\frac{c}{2(1+\theta)}\}^2] - b\{l^2 - (\frac{c}{2b})^2\}$. Since $\lim_{b\to\infty} W = \infty$ and $\lim_{b\to 0} W = -\infty$, we can conclude that $CS^C > CS^R$ if a linear demand curve has a very flat slope (b is very large), while $CS^R > CS^C$ if the slope gets very steep.

Example 2: Suppose $u(q) = L\ln(q+1)$ where $L(>0)$ is a constant. This utility function also satisfies assumption 3, since $u'(q) = \frac{L}{q+1} > 0$, $u''(q) = -\frac{L}{(q+1)^2} < 0$ for all $q \geq 0$. We have $q^* = D(p) = \frac{L}{p} - 1$ if $p < L$, $p^* = \sqrt{cL}$ and $p_C^* = \sqrt{\frac{cL}{1+\theta}}$ if $c < L < 4c$ from optimization problems of consumers and the firm. Also, we can see that $\eta(p) = \frac{L}{L-p} > 0$ and thus $\eta'(p) = \frac{1}{(L-p)^2} > 0$ so long as $L > p$. The observation that $p_C^* + p_R^* = (1+\theta)p_C^* = \sqrt{(1+\theta)cL} > p^*$ confirms proposition 3. Consumer surplus under two systems respectively is computed as $CS^C = (1+\theta)L\ln\frac{L}{c} - 2L + 2\sqrt{cL}$, $CS^R = (1+\theta)\{L\ln(1+\theta)\frac{L}{c} - 2L + 2\sqrt{\frac{cL}{1+\theta}}\}$. Then, $\phi(\theta, L) \equiv CS^C - CS^R = L\{2\sqrt{c}(1 - \frac{1}{\sqrt{1+\theta}}) - (1+\theta)\sqrt{L}\ln(1+\theta)\} < \phi(\theta, c)$. Since $\phi(0, c) = 0$ and $\frac{\phi(\theta,c)}{\theta} = (1+\theta)^{-\frac{3}{2}} - 1 - \ln(1+\theta) < 0$ for all $\theta > 0$, we have $\phi(\theta, L) < 0$ for all $\theta \in (0, 1]$ and $c < L < 4c$, so that $CS^R > CS^C$ in this case.

Example 3: Suppose $u(q) = \frac{q^{1-\frac{1}{\eta}}}{1-\frac{1}{\eta}}$, where $\eta > 1$. This utility yields a constant price elasticity of demand. Straightforward algebra leads us to $q^* = D(p) = p^{-\eta}$, $p^* = \frac{\eta}{\eta-1}c$ and

$p_C^* = \frac{1}{1+\theta}\frac{\eta}{\eta-1}c$. Notice that $p_C^* + p_R^* = p^*$. Also, we have $CS^C = \{(1+\theta)\frac{\eta}{\eta-1} - 1\}(p^*)^{1-\eta}$ and $CS^R = \frac{(1+\theta)^\eta}{\eta-1}(p^*)^{1-\eta}$. Therefore, $CS^R - CS^C = \frac{2}{\eta-1}\{(1+\theta)^\eta - (\theta\eta+1)\}(p^*)^{1-\eta} > 0$, since $(1+\theta)^\eta > \theta\eta + 1$ for all $\eta > 1$.

The result that consumers can be better off under RPP would be far from surprising. Under CPP, each consumer chooses the amount of callings equating his marginal utility of call-makings to the price ($u'(q_i^*) = p$). However, since each call-making generates positive call externalities on the other party, calls are underconsumed under this regime. Notice that, given the price, consumers could be both better off by making more calls.[14] On the other hand, under RPP, call externalites are internalized; the calling party equates his marginal utility of call-makings to the calling prcie ($u'(q_{i,C}^*) = p_C$) and the receiving party equates his marginal utility of call-receivings to the receiving price ($v'(q_{i,R}^*) = p_R$), and as a result, the externalities created by the caller are paid for by the receiving party.[15]

D. Discussion on the assumption of the additive separability

We have assumed that the utility function of each consumer is additively separable. Due to this assumption, the marginal utility of making (receiving respectively) a call does not depend on the amount of calls received (made), so that the quantity of calls that a consumer intends to make (receive) will be determined independent of the quantity of calls that he intends to receive (make) unless the budget constraint is binding.

Although this assumption simplifies the analysis significantly, it is also true that the independence property[16] implied by this assumption is a restrictive feature of the model. It

[14]This cooperation may be possible in a noncooperative way if the consumers are intimate friends or family, so that they interact with each other infinitely often. In that case, according to the conventional supergame literature, consumers can internalize externalities and achieve efficiency by agreeing to make the number of calls per unit period that maximizes their total indirect utility (from making and receiving calls) and reverting to the one-period equilibrium outcome forever thereafter if either party breaks the agreement.

[15]The possibility that consumer welfare may be decreased under RPP is caused by the monopoly power of the firm. However, if prices of the firm are regulated in a way that the regulated prices are equal to the marginal cost under the constraint that no call is refused i.e., $\overline{p} = c$, $\overline{p}_C = \frac{c}{1+\theta}$, $\overline{p}_R = \frac{\theta}{1+\theta}c$, consumer surplus would always be larger under RPP.

[16]This does not imply that there is no substitutability between calls made and calls received.

may be more plausible that the optimal amounts of calls that a consumer intends to make and receive are interrelated with each other. More specifically, it is highly likely that an increase in the amount of calls received decreases the marginal utility of calls made, thereby leading him to make fewer calls. Below, we will see how the results obtained so far can be affected if the utility function is not additively separable.

Suppose consumers have the CES utility function given by

$$U^i(q_{i,C}, q_{i,R}) = A(\alpha_1 q_{i,C}^{\rho} + \alpha_2 q_{i,R}^{\rho})^{\frac{1}{\rho}},$$

where $\rho < 1$. The optimization problem of each consumer under RPP yields the following first order conditions.

$$\frac{\partial V_i^R}{\partial q_{i,C}} = A\alpha_1 (q_{i,C}^*)^{\rho-1} K^{\frac{1}{\rho}-1} - p_C = 0 \tag{12}$$

$$\frac{\partial V_i^R}{\partial q_{i,R}} = A\alpha_2 (q_{i,R}^*)^{\rho-1} K^{\frac{1}{\rho}-1} - p_R = 0, \tag{13}$$

where $K \equiv \alpha_1 (q_{i,C}^*)^{\rho} + \alpha_2 (q_{i,R}^*)^{\rho}$. These equations give us

$$\frac{q_{i,C}^*}{q_{i,R}^*} = (\frac{\alpha_1 p_R}{\alpha_2 p_C})^{\varsigma}, \tag{14}$$

where $\varsigma \equiv \frac{1}{1-\rho}$. ς is usually called the elasticity of substitution. Therefore, as calls made and calls received are considered as more substitutable i.e., ς becomes larger, the difference between $q_{i,C}^*$ and $q_{i,R}^*$ gets bigger. Also, since each consumer has the identical utility function, we have $q_{i,C}^* = q_C^*$ and $q_{i,R}^* = q_R^*$ for all $i = 1, 2$. Thus, the condition for no call to be refused, $q_C^* \leq q_R^*$, is reduced to $p_R \leq \frac{\alpha_1}{\alpha_2} p_C$. Since this condition must be binding for profit maximization of the firm, it is implied that $p_R^* = \frac{\alpha_1}{\alpha_2} p_C^*$ i.e., $\alpha_1 p_C^* = \alpha_2 p_R^*$. The rest of the analysis given in subsection B will remain unaffected qualitatively.

3 A General Model with Two Networks

In this section, we relax some assumptions made in section 2 and extend our discussion to a more general model. Main changes in assumptions are as follows. First, we consider a situation in which there are two substitutable networks rather than only one network. Second, we posit a continuum of consumers who may differ in their tastes instead of two representative consumers. Finally, we abandon the assumption that consumers' network affiliation is fixed and consider their subscription decision as well.

We adapt Hotelling's linear city model to analyze competition between two differentiated networks. Consumers are uniformly distributed over $[0,1]$. Two firms are supplying differentiated networks, and one of them ("firm 1") is located at $x_1 = 0$ and the other ("firm 2") is at $x_2 = 1$. For parsimony of notation, we will use an index i to indicate a firm.

Each firm has the following cost structure. It incurs a variable cost c per (either inbound or outbound) call. c is assumed to be equal to $2c_0$. We may think of c_0 as the equal costs of transmitting voice signals from originating ends to a switcher and from a switcher to terminating ends. The rest of the assumptions on costs made in the previous section are preserved.

Let q_{xy} denote the number of calls a consumer located at x makes to a consumer at y and $U^x(q_{xy}, q_{yx}; y \in [0,1])$ denote the utility function of a consumer at x when he makes q_{xy} calls to a consumer at y and receives q_{yx} calls from him for $y \in [0,1]$. By abusing notation $u(\cdot)$, $v(\cdot)$, we make assumptions on $U^x(\cdot,\cdot)$ which are essentially the same as those in the previous section.

Assumption 4 *$U^x(\cdot,\cdot)$ is additively separable i.e.,* $U^x = \int_0^1 u(q_{xy})dy + \int_0^1 v(q_{yx})dy$

Assumption 5 $v(\cdot) = \theta u(\cdot)$ *for some* $\theta \in (0,1]$.

Assumption 6 $u(0) = 0$, $u'(\cdot) > 0$ *and* $u''(\cdot) < 0$

We model the interaction among the firm and the consumers as a four-stage game. In the first stage, firms agree upon the reciprocal access charge a for interconnection between networks,[17] and in the second stage, they choose their pricing schedules simultaneously. In the third stage, consumers pick a network that they will subscirbe to, and in the final stage, the subscribers choose their quantities of callings simultaneously. We assume that consumers are not allowed to subscribe to more than one network. Also, we assume that

[17] U.S. imposes reciprocity by law, (See the Telecommunications Act of 1996, section 251, b5.) while some other countries (e.g., Korea, Japan, New Zealand, Mexico) do not. (See the Ovum report by Ladbrook and Jeffery (1999).) Theoretically, imposing reciprocity eliminates the problem of double marginalization that appears under nonreciprocal access pricing.

any given consumer is equally likely to call any other consumer, regardless of the network he joins i.e., for any x, $q_{xy} \equiv q_x$ for all y.[18]

The valuation of a consumer at x joining network i and consuming (q_x, q_y) is assumed to be

$$V_i(x) = r - t|x - x_i| + U^x(q_x, q_y) - T_i(q_x, q_y), \qquad (15)$$

where r is the direct benefit from joining a network,[19] $t|x - x_i|$ is the disutility from departure from the favorite service characteristics of a consumer at x and $T_i(q_x, q_y)$ is the amount of money that should be paid for (q_x, q_y). t can be interpreted as a measure of product differentiation between two telecommunication services provided by network 1 and network 2.

We assume throughout that the market is covered, so that $N_1 \cup N_2 = [0, 1]$ where N_i is the set of subscribers to firm i.[20]

Before we begin the analysis, we make some simplifying assumptions.

Assumption 7 $D''(p) = 0$ *for all* p *where* $u'(D(p)) = p$.

Assumption 8 $0 < \Pi^m, \tilde{\Pi}^m < 2(1 + \theta)t$ *where* $\Pi^m \equiv \max_p \Pi(p) = (p - c)D(p)$, $\tilde{\Pi}^m = \max \tilde{\Pi}(p) \equiv \{(1 + \theta)p - c\}D(p)$.

Assumption 7 implying that $u''(\cdot)$ is a constant simplifies the analysis a great deal. Assumption 8 is a technical assumption which ensures that the degree of product differentiation, t, is sufficiently high.

A. Caller Pays Principle

We solve this by backward induction. Suppose the reciprocal access charge a is agreed upon, prices of two firms p_1, p_2, are set, and the resulting market share of firm 1 is given by σ.

[18]Many authors (Rohlfs (1974), Laffont et al. (1998a, b), Armstrong (1998), Economides et al. (1998)) used this so-called "balanced (or uniform) calling pattern assumption", even though they admit that it is obviously not true in reality. Doyle et al. is one exception.

[19]Here, we are assuming that the direct benefits from joining network 1 and network 2 are the same.

[20]This may be justified by the assumption that r is very large.

Then, the optimization problem of a consumer located at x who joins network i is

$$\max_{q_x} U^x(q_x, q_y) - T_i(q_x, q_y) = U^x(q_x, q_y) - p_i q_x = u(q_x) + \int_0^1 v(q_y)dy - p_i q_x \quad (16)$$

The first order condition of this problem implies

$$u'(q_x^{i*}) = p_i, \quad (17)$$

where q_x^{i*} is the optimal amount of callings of a consumer located at x who subscribes to network i. As in section 2, we can write the demand function of a consumer at x joining network i as $q_x^{i*} = D(p_i)$ for all x.

In determining his network affiliation, a consumer at x correctly anticipates what q_x^{i*} and $q_{y,j}^*$ for all y and for all $i, j = 1, 2$ will be, and compare $\hat{V}_1^C(x)$ and $\hat{V}_2^C(x)$ where $\hat{V}_i^C(x)$ is the equilibrium valuation of a consumer located at x joining network i under CPP. In this case, we have

$$\begin{aligned} \hat{V}_1^C(x; p_1, p_2) &= r - tx + u(q_x^{1*}) + \int_{y \in N_1} v(q_y^{1*})dy + \int_{y \in N_2} v(q_y^{2*})dy - p_1 q_x^{1*} \\ &= r - tx + u(D(p_1)) + n_1 v(D(p_1)) + n_2 v(D(p_2)) - p_1 D(p_1), \quad (18) \end{aligned}$$

$$\hat{V}_2^C(x; p_1, p_2) = r - t(1-x) + u(D(p_2)) + n_1 v(D(p_1)) + n_2 u(D(p_2)) - p_2 D(p_2), \quad (19)$$

where n_i is the measure of N_i, $i = 1, 2$. Then, the equilibrium market share σ^* must satisfy $\hat{V}_1^C(\sigma^*; p_1, p_2) = \hat{V}_2^C(\sigma^*; p_1, p_2)$, and thus, by using $n_1 = \sigma^*$, we obtain

$$\sigma^*(p_1, p_2) = n_1^*(p_1, p_2) = \frac{1}{2} + \frac{1}{2t}\{\nu(p_1) - \nu(p_2)\}, \quad (20)$$

where $\nu(p_i) = u(D(p_i)) - p_i D(p_i)$.

We will solve the price setting stage, taking the reciprocal access charge as given, and then look at the determination of the access charge. For a given access charge a, firm i's profit is

$$\pi_i(p_1, p_2; a) = n_i^*(p_i - c)D(p_i) + n_i^* n_j^*(a - c_0)(D(p_j) - D(p_i)), j \neq i \quad (21)$$

This means that the profit of a firm is the sum of the profit from inbound calls and the net monetary inflow from interconnection. The first order conditions of the profit maximization problems imply that the symmetric Nash price p^* must satisfy

$$(p^* - c)\{D(p^*)^2 - tD'(p^*)\} - tD(p^*) + \frac{t}{2}(a - c_0)D'(p^*) = 0 \quad (22)$$

or

$$\frac{1}{t}\Pi(p^*) = 1 - \frac{p^* - c - \frac{1}{2}(a - c_0)}{p^*}\eta(p^*) \tag{23}$$

Unfortunately, neither the existence of the symmetric Nash equilibrium nor the uniqueness of the equilibrium is guaranteed for all a. In particular, if the access charge is very high, a firm will find it profitable to make its own subscriber choose a small number of callings by increasing its price, in order to enjoy a high access surplus, and this incentive may make no price in a relevant range be an equilibrium one. However, it is quite plausible to have a symmetric equilibrium, if a is very close to c_0. To see that, denote left hand side of (20) by $\Psi(p)$. We have $\Psi(c) > 0$, $\Psi(\overline{p}) < 0$ where $D(\overline{p}) = 0$. Since $\Psi(p)$ is continuous in p, there exists a symmetric equilibrium $p^*(a)$ satisfying (20) in a relevant range of p, $[c, \overline{p}]$. (See figure 3.)

Assuming that there exists an equilibrium, we have the following proposition.

Proposition 6 *Under assumption 7 and assumption 8, p^* is increasing in a.*[21]

Proof. See the appendix.

The intuition behind proposition 6 is that, if a is increased, it will be optimal for a firm to charge a higher price in order to decrease the demand for calls originating from it, thereby increasing an access surplus.[22]

Now, let us look for the collusive reciprocal access charge. To maximize joint profits, the colluding firms will set their reciprocal access charge a^C satisfying $\frac{\partial\Pi(p^*(a^C))}{\partial a} = 0$. Therefore, it must be that $p^*(a^C) = p^m$ where p^m maximizes $\Pi(p)$. The following proposition displays some properties of a^C.

Proposition 7 *(i) The access charge under CPP, a^C, is strictly higher than the marginal cost of access, c_0. (ii) a^C is decreasing in t and approaches c_0 as $t \to \infty$.*

Proof. See the appendix.

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[21] In fact, without assumption 8, we can show that, if $a \leq c_0$, $p^*(a) < p^m$ and $p^*(a)$ is increasing in a, if $p^*(a)$ ever exists, since $\Psi'(p) = \frac{D'}{D}[1 - \{p^* - c - \frac{1}{2}(a - c_0)\}\frac{D'}{D}] < 0$, $\Psi(p^m) = -\frac{1}{2}(a - c_0)\frac{D'(p^m)}{D(p^m)} \leq 0$ and $\Pi(p^m) \neq 0$. (See figure 4.)

[22] If t is very small, however, an increase in p may result in losing a large number of subscribers. If this effect exceeds the effect of increasing an access revenue, the equilibrium price p^* may be decreasing in a.

The last part of this proposition implies that $a^C \approx c_0$ if t is so large that consumers' subscription decision is very insensitive to a change in the prices,[23] which is consistent with the results of Armstrong (1998) and Laffont et al. (1998a).[24]

B. Receiver Pays Principle

We now consider the case where both firms operate under the receiver pays principle. Let $p_{i,C}$ ($p_{i,R}$ respectively) denote the price that firm i charges for calls made (received). Also, let $q_{xy,C}$ ($q_{xy,R}$ respectively) be the quantity that a consumer at x makes to (received from) a consumer at y. Then, the assumption of the balanced calling pattern implies that $q_{xy,C} \equiv q_{x,C}$ for all y and that $q_{xy,R} = q_{x,i,R}$ if $y \in N_i$ where $q_{x,i,R}$ is the quantity of calls that a consumer at x receives from another consumer belonging to network i.[25] Notice that a caller does not need to be concerned about which network he is calling to, while a receiver must be concerned about from which network he is receiving a call.

Given the prices $p_{i,C}$, $p_{i,R}$, $i = 1, 2$ and the market share σ, a consumer at x who joins network i faces the following optimization problem

$$\begin{aligned} \max_{\{q_{xy,C}, q_{xy,R}\}_{y \in [0,1]}} \quad & U^x(q_{xy,C}, q_{xy,R}) - T_i(q_{xy,C}, q_{xy,R}) \\ = \quad & u(q_{x,C}) + \sum_{i=1}^{2} \int_{y \in N_i} v(q_{xy,R}) dy - p_{i,C} q_{x,C} - \sum_{i=1}^{2} \int_{y \in N_i} p_{i,R} q_{xy,R} \end{aligned} \tag{24}$$

First order conditions imply that

$$u'(q^{i*}_{x,C}) = p_{i,C}, x \in N_i \tag{25}$$

$$v'(q^{i*}_{xy,R}) - p_{j,R} = 0, y \in N_j, j = 1, 2 \tag{26}$$

where $q^{i*}_{x,C}$ ($q^{i*}_{xy,R}$ respectively) is the optimal number of calls that a consumer at x who joins network i intends to make (to receive from another consumer at y) under RPP.

[23] This can be seen from $\frac{\partial N_i^*}{\partial p_i} = -\frac{\partial N_j^*}{\partial p_i} = -\frac{D(p^*)}{2t}$, $j \neq i$

[24] This corresponds to the case that $s'(0) = 0$ in Armstrong (1998) and $\sigma = 0$ in Laffont et al. (1998a).

[25] Here, we are implicitly assuming that a receiver can tell which network a particular call originates from. In practice, this may be possible by various mechanisms for distinguishing between wanted and unwanted calls that were mentioned in the introduction.

Again, if we impose the condition that no call is refused, we must have

$$q^{i*}_{x,C} \leq q^{j*}_{yx,R}, q^{i*}_{xy,R} \geq q^{j*}_{y,C}, y \in N_j, i,j = 1,2 \tag{27}$$

Then, it can be shown that the condition of no call refusal given by (24) is reduced to $p_{j,R} \leq \theta p_{j,C}$ in a similar way as in section 2.

As seen in the case of CPP, the equilibrium market share under RPP, σ^{**}, is determined as a result of the subscription decision of consumers who compare $\hat{V}_1^R(x)$ and $\hat{V}_2^R(x)$ where

$$\hat{V}_i^R(x) = r - t|x - x_i| + U^x(q^{i*}_{x,C}, q^{i*}_{x,1,R}, q^{i*}_{x,2,R}) - T_i(q^{i*}_{x,C}, q^{i*}_{x,1,R}, q^{i*}_{x,2,R})$$

Thus, σ^{**} can be found by $\hat{V}_1^R(\sigma^{**}) = \hat{V}_2^R(\sigma^{**})$, so that $\sigma^{**}(p_{1,C}, p_{2,C}) = \frac{1}{2} + \frac{1}{2t}(\nu(p_{1,C}) - \nu(p_{2,C}))$. Notice that the market share is not affected by the prices for receiving calls. A consumer receives the same number of calls from each network no matter which network he joins, thereby he pays the same for receiving calls in either case regardless of the receiving prices, which implies that his subscription decision can never be affected by the receiving prices charged by firms.

Given the access charge a, firm i solves

$$\max_{p_{i,C}, p_{i,R}} \pi_i^R = n_i^{**}(p_{i,C} + p_{i,R} - c)D(p_{i,C}) + n_i^{**}n_j^{**}(a - c_0)(D(p_{j,C}) - D(p_{i,C})), j \neq i \tag{28}$$

$$\text{subject to } \theta p_{i,C} \geq p_{i,R},$$

where n_i^{**} is the equilibrium number of subscribers to network i under RPP which is equal to $\sigma^{**}(p_{1,C}, p_{2,C})$. In this general case, too, $p_{i,R}(\neq \theta p_{i,C})$ cannot be optimal for firm i, since a slight increase in $p_{i,R}$ could leave the number of subscribers to firm i and their callings unaffected, thereby increasing the profit. Thus, the optimization problem given by (25) can be simplified into

$$\max_{p_{i,C}} \hat{\pi}_i^R(p_{i,C}) = n_i^{**}\{(1+\theta)p_{i,C} - c\}D(p_{i,C}) + n_i^{**}n_j^{**}(a - c_0)\{D(p_{j,C}) - D(p_{i,C})\} \tag{29}$$

The first order conditions imply that the symmetric equilibrium calling price p_C^* must satisfy

$$\{(1+\theta)p_C^* - c\}\{D(p_C^*)^2 - tD'(p_C^*)\} - t(1+\theta)D(p_C^*) + \frac{t}{2}(a - c_0)D'(p_C^*) = 0 \tag{30}$$

or

$$\frac{1}{t}\tilde{\Pi}(p_C^*) = 1 + \theta - \frac{(1+\theta)p_C^* - c - \frac{1}{2}(a - c_0)}{p_C^*}\eta(p_C^*) \tag{31}$$

Assuming that a symmetric equilibrium exists, we can establish the following counterparts of proposition 6 and proposition 7 under RPP. We will omit the proofs, since the proofs of proposition 6 and 7 can be adapted in a straightforward way.

Proposition 8 *Under assumption 7 and 8, p_C^* is increasing in a.*

Proposition 9 *(i) The collusive access charge under RPP, a^R, exceeds the marginal cost of access, c_0. (ii) a^R is decreasing in t and approaches c_0 as $t \to \infty$.*

Again, the following lemma suggests that we can content ourselves with the solution with the constraint that no call is refused.

Lemma 3 *A pair of symmetric prices (p_C, p_R) such that $p_R > \theta p_C$ cannot be profit maximizing.*

Proof. See the appendix.

Intuitively, if a firm charges a slightly higher calling price p_C' than p_C, it increases the number of its subscribers but decreases the number of the rival's subscribers in the same proportion, while it does not affect the number of callings per subscriber at all, since it is determined solely by the receiving price. This leaves the total demand for callings originating from it the same as before; however, it obviously increases the revenues from each subscriber. Therefore, it would be always profitable to charge a higher calling price than p_C, implying that the onging price pair (p_C, p_R) cannot be part of an equilibrium. We now summarize with

Proposition 10 *The profit-maximizing price vector under RPP is (p_C^*, p_R^*) where p_C^* satisfies (28) and $p_R^* = \theta p_C^*$.*

C. Comparison

We are now ready to compare the outcomes under two regimes. For our purpose, it will be convenient to introduce a parameter to integrate two equations (19) and (20) into one equation as follows;

$$(\lambda p - c)D(p)^2 = t[\lambda D(p) + \{\lambda p - c - \frac{1}{2}(a - c_0)\}D'(p)], \tag{32}$$

where $\lambda = 1$ under a caller pays regime and $\lambda = 1 + \theta$ under a receiver pays regime. Let us allow an imaginary change in λ continuously from 1 to $1 + \theta$. Denoting p satisfying (29) by $\hat{p}(a, \lambda)$, we have $\hat{p}(a, 1) = p^*(a)$ and $\hat{p}(a, 1 + \theta) = p_C^*$. Then, the following propositions can be established.

Proposition 11 *$p^*(a) > p_C^*(a)$ for all a such that both $p^*(a)$ and $p_C^*(a)$ exist.*

Proof. See the appendix.

This proposition says that, given a, firms charge higher calling prices under CPP than under RPP. The intuition is that positive receiving prices under RPP have virtually the same effect as reducing the marginal costs, and as a result, profit-maximizing calling prices are lowered under RPP.

Proposition 12 $p^*(a^C) > p_C^*(a^R)$.

Proof. This is immediate, since $p^m = p^*(a^C) > p_C^*(a^R) = p_C^m$.

Proposition 12 implies that the calling price under CPP is higher than under RPP in an equilibrium where the reciprocal access charge is optimally set. However, in general, we cannot tell which of the two, a^C, a^R, is higher.

Now, a natural question that arises is which of the agreed-upon access charge under two regimes is higher. The following proposition provides the answer.

Proposition 13 $a^R > a^C$.

Proof. See the appendix.

Introducing RPP lowers the equilibrium calling price given the access charge, and the higher access charge yields higher calling prices under both regimes. Thus, firms must set a higher access charge under RPP than under CPP to induce the collusive calling price p_C^m so long as it does not differ from the collusive calling price under CPP p^m very much.

Finally, we will see the implication of RPP on profits of firms and consumer surplus. First, it is easy to see that $\hat{\pi}_i^R(p_C^*(a^R)) > \hat{\pi}_i^C(p_C^*(a^C))$ since $\hat{\pi}_i^R(p_C^*(a^R)) = \frac{1}{2}\max\{(1+\theta)p-c\}D(p) > \frac{1}{2}\max(p-c)D(p) = \hat{\pi}_i^C(p_C^*(a^C))$. Also, when firms pick the collusive access charge and charge equilibrium prices, consumer surplus under CPP is computed as $\int_0^{\frac{1}{2}} \hat{V}_1^C(x;p^m,p^m)dx + \int_{\frac{1}{2}}^1 \hat{V}_2^C(x;p^m,p^m)dx = r + (1+\theta)u(D(p^m)) - p^m D(p^m) - \frac{t}{4}$, and, similarly, consumer surplus under RPP is as $\int_0^{\frac{1}{2}} \hat{V}_1^R(x;p_C^m,p_C^m)dx + \int_{\frac{1}{2}}^1 \hat{V}_2^R(x;p_C^m,p_C^m)dx = r + (1+\theta)u(D(p_C^m)) - (1+\theta)p_C^m D(p_C^m) - \frac{t}{4}$. Therefore, the effect of RPP on consumer surplus is exactly identical to the case of a single network described in section 2, as long as the form of the utility function is the same in the two cases. Proposition 14 summarizes this.

Proposition 14 *The collusive joint profits are larger under RPP than under CPP, but the effect of RPP on consumer surplus is ambiguous.*

4 Concluding Remarks and Caveats

In this paper we have explored the effect of the receiver pays principle (RPP) both in a model with one PSTN and in a model with one PSTN and one mobile network. Our main findings are that, under mild conditions, RPP can increase not only the consumer surplus but also the firm's profit and that RPP makes firms set a higher reciprocal access charge than CPP does.

In practice, it will be a controversial issue whether replacing CPP by RPP will improve social welfare or not. The regulatory authority who concerns itself with maximizing consumer surplus may hesitate to adopt RPP on the ground that it may reduce consumer surplus since the inelastic demand for telecommunication services will keep p_C^* high enough. However, we strongly believe that it is not very likely to occur because consumer surplus will be increased under RPP unless the price elasticity of demand gets smaller very rapidly as the price falls.

To the best of our knowledge, this is the only paper that deals with the receiver pays principle in telecommunications pricing except Doyle and Smith (1998). Their main interest, however, lies in the effect of RPP on prices of calls to mobiles.[26] In their model, a mobile service provider sets a total posted price of a fixed to a mobile call and a mobile subscriber receiving a call from a fixed phone pays the amount equal to the total posted price minus the

[26]There had been a great concern expressed by U.K. customers who felt that the prices of calling to a mobile phone were unduly high before OFTEL's investigation into the prices in June 1996. See OFTEL (1998).

charge paid by the call originator.[27] After all, the price for receiving a call is determined by the mobile service provider to which the receiver subscribe, which is the main feature that is distinguished from our model. Also, in order to avoid complexities involved with price discrimination between on-net and off-net calls, they assume that all calls made by mobile subscribers terminate on the fixed network. In our opinion, their analysis is somewhat incomplete both in the sense that their results are obtained on a number of restrictive assumptions and that no welfare implication is included.

We may consider various alternative models. First, firms may use more general tariffs than the simple linear pricing used throughout in this paper. If firms offer two-part tariffs instead of linear tariffs, for example, incorporating RPP will affect the usage fee while it will leave the fixed fee unaffected. RPP functions as lowering the usage fee for the caller but it does not affect the fixed fee.[28] Also, firms can price discriminate between on-net calls an off-net calls. This kind of price discrimination under CPP is analyzed in details in Laffont et al. (1998b) and it would be possible to extend their arguments to the regime where the receiver pays some. Second, it is common that two networks have different cost structures. In particular, the marginal cost of mobile termination is much higher than that of fixed termination in practice. In this case, the desired access charges of each network will certainly be different and it seems unfair to the mobile service provider to require the reciprocal access charge. However, if we do not impose reciprocity of access charge, the consequence that each firm sets a separate access charge would be high access charges due to double marginalization. (Laffont et al. (1998a)) In this respect, it will deserve to see how the effect of introducing RPP on the access charges can be affected in this nonreciprocal environment. Third, firms may adopt an alternative payment system whereby the called party pays all as in the U.S. mobile service. Or, firms may collect charges from their respective subscribers themselves as interconnection charges whenever they receive calls from the other network rather than allow the other network to collect the charges and then make settements afterwards. However, such schemes will be generally suboptimal since they are just special cases of the general scheme

[27]This mechanism also enables callers to be free from concerns about whether the calls they are making terminate on a fixed or mobile network.

[28]First order conditions of the profit maximization problem imply that $F_i^C = F_i^R = t$ where F_i^C (F_i^R) is the fixed fee charged by firm i under CPP (RPP respectively).

considered in section 3. Fourth, we may endogenize the firms' decisions about whether they will choose CPP or RPP. If one firm adopts RPP and the other does CPP, a consumer who subscribes to the service provider adopting CPP will pay the whole price for his making calls and be charged for calls received from the other network as well and thus it is expected that the network size of the firm adopting RPP will be larger. Therefore, we conjecture that both firms will adopt RPP in equilibrium. Finally, in reality, several mobile telephony companies are operating together with one PSTN provider or two PSTN providers. In particular, if there are several PSTN's and several mobile networks involved, we may address the issue of strategic alliances between a PSTN and a mobile network which are exclusive to each other.

Appendix

Proof of Lemma 2:

Consider a price vector $(\hat{p_C}, \hat{p_R})$ such that $\hat{p_C} < \frac{\hat{p_R}}{\theta}$. This implies $\hat{q}_{i,R}(\hat{p_R}) = D(\frac{\hat{p_R}}{\theta}) < D(\hat{p_C}) = \hat{q}_{j,C}(\hat{p_C})$, $i \neq j$ where $\hat{q}_{i,R}(p_R)$ and $\hat{q}_{i,C}(p_C)$ are defined as satisfying $u'(\hat{q}_{i,C}(p_C)) = p_C$, $v'(\hat{q}_{i,R}(pR)) = p_R$ respectively. Then, we can choose $\epsilon > 0$ such that $p'_C = \hat{p_C} + \epsilon < \frac{\hat{p_R}}{\theta}$ and still $\hat{q}_{i,R}(\hat{p_R}) < \hat{q}_{j,C}(p'_C)$. It is obvious that $\pi^R(p'_C, \hat{p_R}) > \pi^R(\hat{p_C}, \hat{p_R})$.

Proof of Proposition 5:

If $p^* = (1+\theta)p^*_C + \epsilon$ for some $\epsilon \geq 0$, we have

$$\begin{aligned}
CS^R - CS^C &= (1+\theta)\sum_{i=1}^{2}\{\int_0^{q^*_{i,C}} u'(q)dq - p^*_C q^*_{i,C}\} - \sum_{i=1}^{2}[(1+\theta)\int_0^{q^*_i} u'(q)dq - \{(1+\theta)p^*_C + \epsilon\}q^*_i] \\
&= (1+\theta)\sum_{i=1}^{2}\{\int_{q^*_i}^{q^*_{i,C}} u'(q)dq - p^*_C(q^*_{i,C} - q^*_i)\} + \epsilon\sum_{i=1}^{2} q^*_i \\
&> (1+\theta)\sum_{i=1}^{2}\{u'(q^*_{i,C})(q^*_{i,C} - q^*_i) - p^*_C(q^*_{i,C} - q^*_i)\} + \epsilon\sum_{i=1}^{2} q^*_i \\
&= \epsilon\sum_{i=1}^{2} q^*_i \geq 0
\end{aligned}$$

Proof of Proposition 6:

Total differentiation of (20) gives us $\frac{dp^*(a)}{da} = \frac{\Psi_a}{\Pi_p - \Psi_p}$. In equilibrium, we have $\Psi_p = \frac{D'}{D}[1 - \{p^*(a) - c - \frac{1}{2}(a - c_0)\}\frac{D'}{D}] = \frac{D'}{D}\{2 - \frac{\Pi(p^*(a))}{t}\} < 0$ by equation (20) and assumption 8. If $p^*(a) \leq p^m$ implying $\Pi_p(p^*(a)) \geq 0$, we have $\frac{dp^*(a)}{da} > 0$, since $\Psi_a = -\frac{1}{2}\frac{D'}{D} > 0$.

On the other hand, a bit more of calculus shows that $\frac{dp^*(a)}{da} = -\frac{\frac{t}{2}D'}{\Delta}$ where $\Delta = D^2 - 2tD' + 2(p^* - c)DD'$. Also, the second order condition requires that $2D^2 + D'\{3(p^* - c)D - 2t\} > 0$. Using this, we have

$$\begin{aligned} \Delta &> D^2 - 2D^2 - (p^* - c)DD' \\ &= -D\{(p^* - c)D' + D\} > 0, \end{aligned}$$

since $(p^* - c)D' + D < 0$ if $p^* > p^m$. Therefore, the conclusion follows that $\frac{dp^*(a)}{da} > 0$.

Proof of Proposition 7:

Substituting $a = c_0$ into (20) and multiplying both sides by $D(p^*(c_0))$, one has

$$(p^*(c_0) - c)D'(p^*(c_0)) + D(p^*(c_0)) = \frac{D(p^*(c_0))}{t}\Pi(p^*(c_0)) \qquad (A1)$$

Assumption 8 implies that $p^*(c_0) \neq p^m$. Also, the nonnegativity of symmetric equilibrium profits implies that $\Pi(p^*(a)) > 0$ for all a. Thus, it follows that $p^m \equiv p^*(a^C) > p^*(c_0)$, so that $a^C > c_0$ by proposition 6. (See figure A-1.) The proof of the second part is obvioius.

Proof of Lemma 3:

If $p_R > \theta p_C$, we have

$$\begin{aligned} \hat{V}_i^R(x) &= r - t|x - x_i| + \int_0^1 u(D(\frac{p_{1,R}}{\theta}))dy + n_1 v(D(p_{1,R})) + n_2 v(D(p_{2,R})) \\ &\quad - p_{i,C}\{n_1 D(\frac{p_{1,R}}{\theta}) + n_2 D(\frac{p_{2,R}}{\theta})\} - n_1 p_{1,R} D(p_{1,R}) - n_2 p_{2,R} D(p_{2,R}) \end{aligned}$$

Suppose $(\hat{p}_C, \hat{p}_R)$ such that $\hat{p}_R > \theta \hat{p}_C$ is a symmetric equilibrium price vector. Simple algebra leads to $\sigma^{**} = n_1^{**} = \frac{1}{2} + \frac{1}{2t}(\hat{p}_C - p_{1,C})\tilde{Q}(\hat{p}_R, \hat{p}_R; \sigma^{**})$ where $\tilde{Q}(p_{1,R}, p_{2,R}; \sigma) = \sigma D(\frac{p_{1,R}}{\theta}) + (1 - \sigma)D(\frac{p_{2,R}}{\theta})$. Also, we have $\pi^R = (p_{i,C} + p_{i,R} - c)\tilde{Q} + n_1^{**} n_2^{**}(a - c_0)\{D(p_{i,R}) - D(p_{j,R})\}$.

If firm i charges $p'_{i,C} = \hat{p}_C + \epsilon$ such that $\hat{p}_R > \theta p_{i,C}$, we have $\frac{\partial \sigma^{**}}{\partial p_{1,C}} = -\frac{1}{2t}\tilde{Q}(\hat{p}_R, \hat{p}_R; \sigma^{**})$ in a symmetric equilibrium, so that $\frac{\partial \pi_i^R}{\partial p_{i,C}} = \tilde{Q}(\hat{p}_R, \hat{p}_R; \sigma^{**}) + (\hat{p}_C + \hat{p}_R - c)\{\frac{\partial n_i^{**}}{\partial p_{i,C}} D(\hat{p}_R) +$

$\frac{\partial n_j^{**}}{\partial p_{i,C}} D(\hat{p}_R)\} = \tilde{Q}(\hat{p}_R, \hat{p}_R; \sigma^{**}) > 0$, implying that firm i always has an incentive to increase p_C.

Proof of Proposition 11:

It is sufficient to show that $\frac{\partial \hat{p}(a,\lambda)}{\partial \lambda} < 0$. Total differentiation of (29) gives $\frac{\partial \hat{p}(a,\lambda)}{\partial \lambda} = \frac{t(D+pD')-pD^2}{\Sigma} = \frac{t(1-\eta)-pD}{D\Sigma}$, where $\Sigma = \lambda D^2 + 2(\lambda p - c)DD' - 2t\lambda D'$. Since $\frac{\partial \hat{p}(a,\lambda)}{\partial a} > 0$ implies that $\Sigma > 0$, we have $\frac{\partial \hat{p}(a,\lambda)}{\partial \lambda} < 0$.

Proof of Proposition 13:

a^C and a^R satisfy

$$\frac{1}{t}\Pi(p^m) = 1 - \frac{p^m - c - \frac{1}{2}(a^C - c_0)}{p^m}\eta(p^m)$$

$$\frac{1}{t}\tilde{\Pi}(p_C^m) = 1 + \theta - \frac{(1+\theta)p_C^m - c - \frac{1}{2}(a^R - c_0)}{p_C^m}\eta(p_C^m)$$

Straightforward computation leads us $a^R - a^C = \frac{2}{t\beta^2}\{(1+\theta)(\frac{\alpha}{2} - \frac{\beta}{1+\theta}c_0)^3 - (\frac{\alpha}{2} - \beta c_0)^3\} > 0$, where $D(p) = \alpha - \beta p$.

Acknowledgement: We are grateful to Hyung Bae, Chang-Ho Yoon, seminar participants at Korea Telecommunications (KT), SK Telecom, audiences at the conference of Korean Industrial Organization Association, the Applied Microeconomics Workshop held at the Korea Foundation for Advanced Studies, the Telecommunications Policy Workshop sponsored by the Korea Association for Telecommunications Policies for helpful comments.

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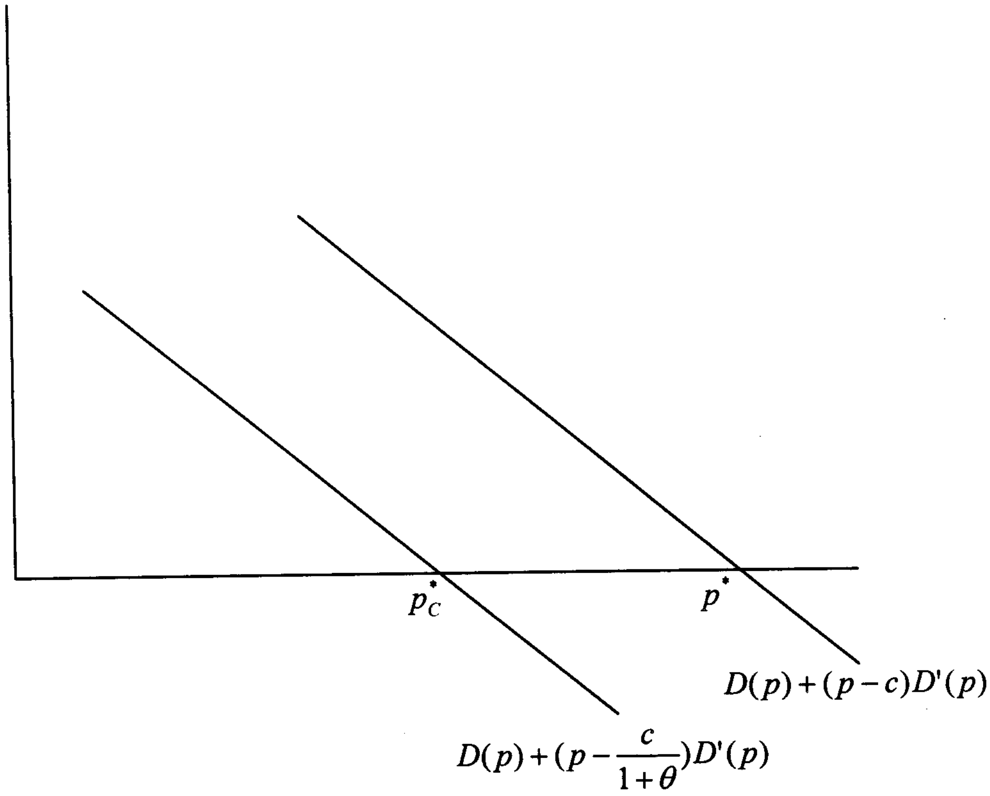


Figure 1

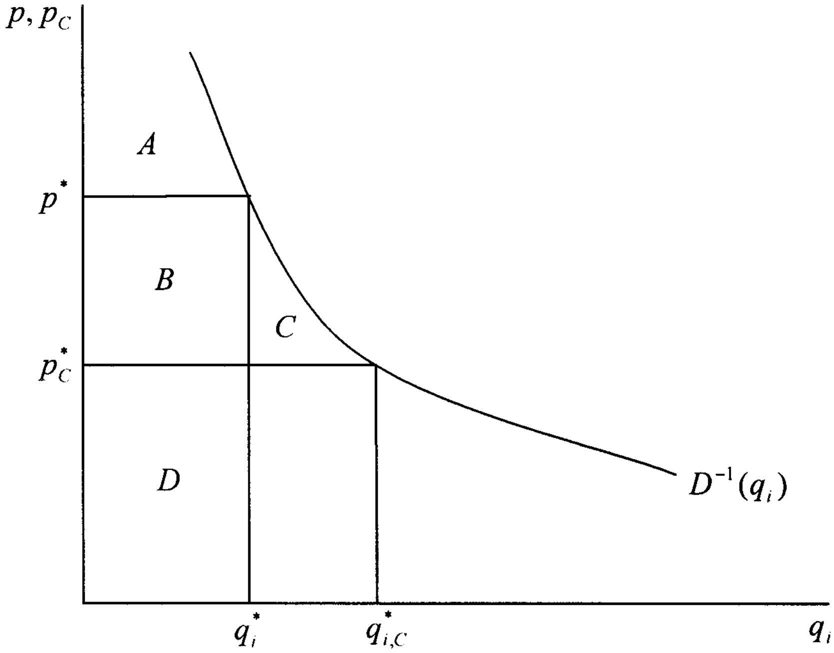


Figure 2

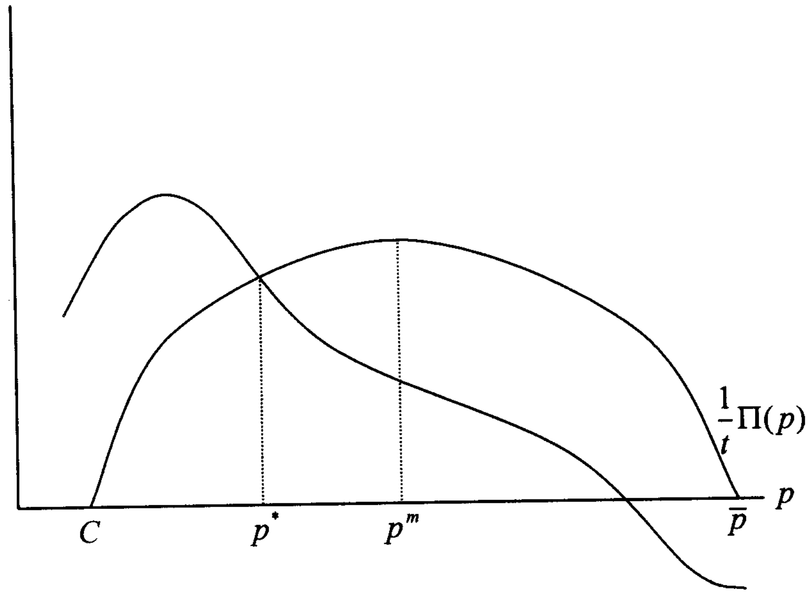
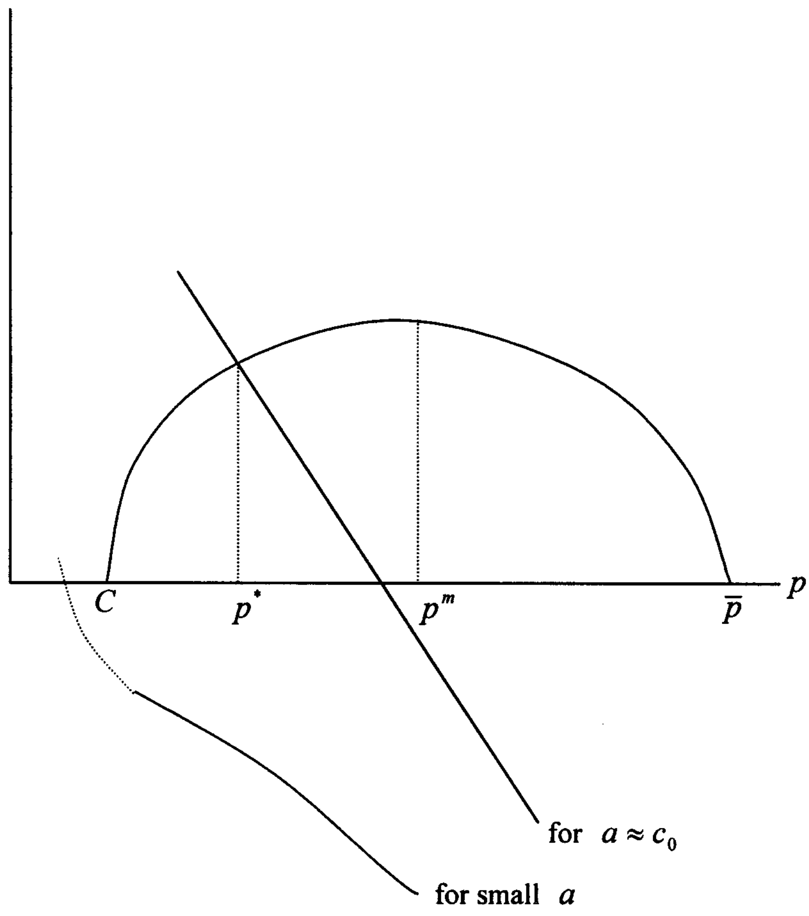


Figure 3



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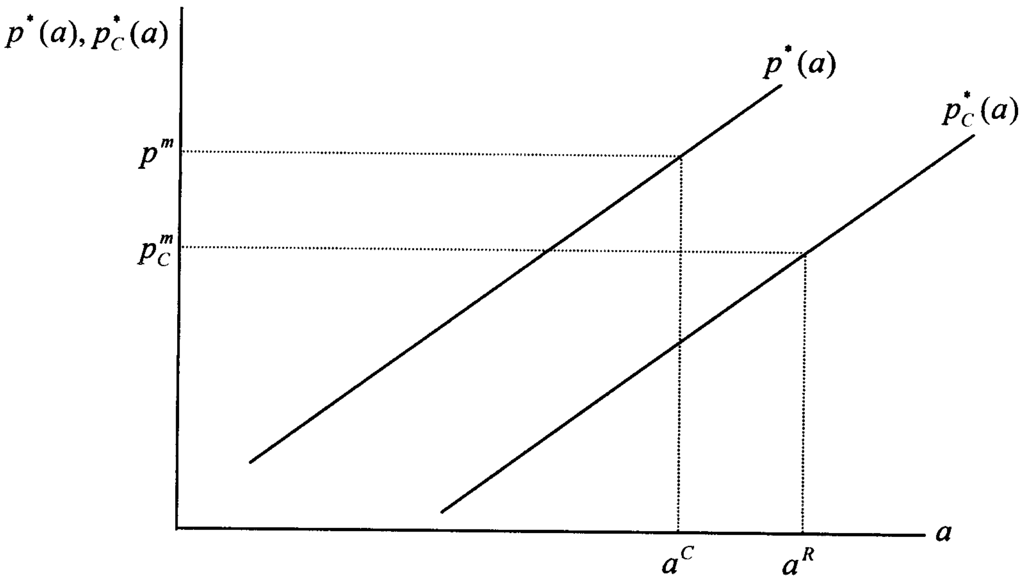

Figure 5

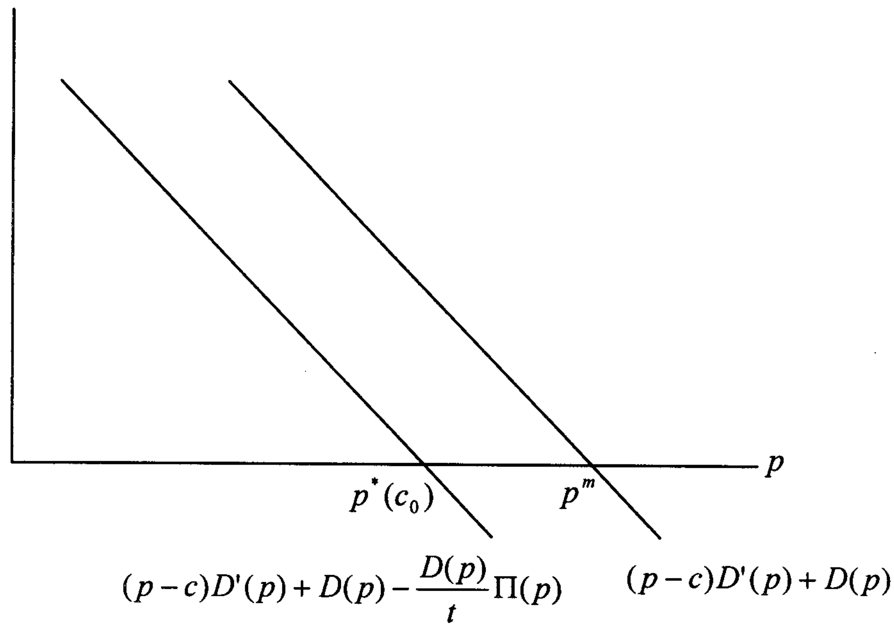

Figure A-1