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Two-Way Interconnection and the Collusive Role of the Access Charge

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Abstract I show that under network competition with termination-based price discrimination access charges *below* marginal cost may be used as a collusion device, if the utility of receiving calls is accounted for. This holds even for linear prices and sharply contrasts recent results in the literature suggesting that collusion over the access charge might result in a markup on cost. Moreover, "bill and keep" arrangements may be welfare improving compared with cost-based access pricing.

Journal of Economic Literature classification numbers: L41, L96.

Key words Network Competition, Two-Way Interconnection, Access Charge, Call Externality

1 Introduction

The telecommunications industry has undergone rapid change in several aspects during the last years. The breakup of former state-owned monopolies and deregulation in the local call market was in many countries accompanied by exorbitantly high growth rates in the mobile telephony market. This has shifted the focus of research in telecommunications to markets characterized by two-way interconnection. In such a market, competing service providers are typically interconnected, and part of their service consists of terminating calls that originate on their rivals' networks. Since this is costly, firms collect per-minute access charges (or interconnection fees) from each other for termination.

From a regulatory viewpoint, an important issue is how to set these access charges. It is commonly agreed that networks competing for customers in linear retail prices should not be allowed to set their access charges noncooperatively. The reason is that this would result in a "double marginalization" problem. Intuitively, by unilaterally increasing its termination charge, a network can raise the marginal call costs of the rival network[1]. This translates into a higher rival's retail price, leading to a lower rival's market share and a higher market share of the own network. In a noncooperative, symmetric equilibrium then, two equal networks will both charge high access fees and high call prices, which may well exceed the monopoly price, if substitutability between networks is low. However, since network traffic tends to be symmetric, only the high prices enter into equilibrium profits, while access charges received and payed out cancel. In sum, profits as well as consumer surplus are low.

One way of alleviating the double marginalization problem is to impose *reciprocity* of access charges, i.e. to demand that both networks charge the same unit access fee. This can be achieved by a regulator setting an appropriate reciprocal access charge, or by letting the networks freely negotiate over the access charge, subject only to reciprocity. In many OECD countries, interconnection arrangements are indeed handled in the latter way, with regulatory intervention only if negotiations fail. Now, while collusion over retail prices is illegal in general, cooperative agreement on the access charge is allowed and often encouraged. This makes sense only if firms are not able to indirectly collude over retail prices by colluding over the access charge. Unfortunately this is by no means obvious.

One has to be careful when judging the role of the access charge. The fact that, due to traffic symmetry, a reciprocal access charge does not explicitly appear in equilibrium profits, does not mean that networks are indifferent about its level.[2] Equilibrium profits do in fact strongly depend on the access

[1] This is called the *raise-each-other's-cost effect* by Laffont and Tirole (2000).

[2] Armstrong (1998) e.g. mentions a paper by the New Zealand Ministry of Commerce supporting this wrong intuition. It was termed the *bill-and-keep fallacy* by Laffont and Tirole (2000).

charge, but only indirectly, through the noncooperatively determined equilibrium call prices which are affected by total termination costs, including access charges.

In the second half of the 1990s, serious concerns have been raised in the literature about firms' ability to use a cooperatively determined access charge as a collusion device (see e.g. Brennan (1997)). As noted already by Katz, Rosston, and Anspacher (1995), networks have an incentive to agree on a high (above marginal cost) reciprocal access charge in order to achieve high end user prices. Together with the confirming results from the first explicit models (see below for details on this literature), this has led many researchers to adopt the view that collusion in the retail market is associated with *high* access charges. This view was only slightly clouded by subsequent opposite results arising from refinements of the basic models, which tried to eliminate some of the less realistic assumptions of these models.

This paper is concerned with one particular assumption routinely invoked by the economic literature on two-way access. It is the assumption that consumers do not benefit from receiving calls. I believe that this is not only unrealistic, but also assumes away a potentially significant effect, which arises if firms can set different prices for calls terminating on-net and off-net, i.e., if they use termination-based price discrimination – what e.g. mobile telephony providers typically do. The reason for this is that with termination-based price discrimination, if consumers care about being called, their total surplus does not only depend on the prices offered by the network they are subscribed to, but also on the price the rival sets for calls into this network. Without this call externality, a network raising its price for off-net calls would only reduce volume demand of its own customers. Taking into account the call externality makes clear that this also hurts the rival's customers, and hence makes the rival less attractive to subscribe to. This effect leads both networks to set higher off-net prices than without the call-externality. Indeed, if receivers' utility is sufficiently great, with linear pricing this may lead to equilibrium off-net prices above the monopoly level, accompanied by rather low on-net prices, even if the access charge is equal to marginal cost. A decrease in the access charge then lowers the off-net price and raises the on-net price, so both prices move towards the monopoly level. This, of course, raises profits, and consequently the collusive level of the access charge is below marginal cost. Since this is also the case for the welfare maximizing access charge, however, letting networks cooperate in determining the access charge might even improve welfare compared to cost-based access regulation.

If networks compete in two-part tariffs, it is known that even without taking into account the call externality the collusive access charge is below cost. If receivers' utility is accounted for, the same intuition as in the linear pricing case leads to even lower collusive access charges. Hence for competition in two-part tariffs, the cooperative choice of the access charge is unambiguously below cost.

The overall impression from these results is that lifting some of the unrealistic restrictions from the standard model makes *high* collusive access charges appear rather the exception than the rule. It also seems as if the marginal costs of call termination might loose their hitherto focal role in the issue of regulating access charges.

The rest of this paper is organized as follows. Section 2 reviews the literature on two-way interconnection and explains the phenomena related to linear and nonlinear pricing, termination-based price discrimination, and the call externality. In Section 3 I introduce the model of LRTb and the specific extension including the call externality in this model. Section 4 explains the notions of consumer equilibrium and network equilibrium. The analysis of the model and the explanation of the diverse results starts with the linear pricing case in Section 5, and continues with the nonlinear pricing case in Section 6. A final discussion concludes.

2 Literature Overview

The first to show the negative welfare effects of cooperatively determined access charges within an explicit model were Armstrong (1998), Laffont, Rey, and Tirole (1998a)– henceforth LRTa, and Carter and Wright (1999). They employ models where two networks are differentiated in the Hotelling style and compete for customers in linear, nondiscriminating prices. The model of LRTa is by now widely accepted as the "standard model" of two-way interconnection, and most of the subsequent literature uses this model as a starting point. Basic assumptions of LRTa's model include that consumers do not benefit from receiving calls and that calling patterns are balanced.[3] All these authors conclude that the negotiated access charge may be used as a collusive device and will definitely exceed the marginal cost of access.

2.1 Nonlinear Pricing

If networks may compete in nonlinear prices, e.g. two-part tariffs, this result does no longer hold. As LRTa show, equilibrium profits are independent of the access charge, leaving networks indifferent about the price of interconnection. The intuition is that although usage fees still increase with the access charge, networks can counterbalance the negative impact on market share by lowering the fixed fee. Thus competition remains strong, and the access charge looses its collusive function.

Dessein (2001) studies a model where consumers differ in volume demand or subscription demand. He shows that introducing heterogeneity in volume demand leaves the neutrality of the access charge unaffected. This result

[3] A balanced calling pattern requires that, ceteris paribus, consumers are equally likely to call customers of both networks, and hence the percentage of on-net calls of a network equals the market share of that network.

is also supported by Hahn (2002). If demand for subscription is elastic, however, some consumers may choose not to subscribe in equilibrium. As Dessein (2001) and Schiff (2002) show, this leads networks to prefer an access charge *below* marginal cost. The reason for this is the emergence of positive network externalities in the absence of full participation.

2.2 Termination-Based Price Discrimination

The mentioned models do best describe local fixed-link telecommunication networks. With the rise of mobile telecommunication, however, the practice of termination-based price discrimination became apparent. In mobile networks it is commonly observed that different prices are charged for calls terminating in different networks. Usually the price for calls terminating in the same network where they originate (on-net calls) is lower than the price for calls leaving the network (off-net calls). Price discrimination of this type creates positive (tariff-mediated) network externalities despite interconnection. Given the observed price structure, a consumer is the better off the larger the market share of the network he is subscribed to.

Termination-based price discrimination was already studied by Economides, Lopomo, and Woroch (1996). However, their results differ substantially from the results discussed below, since they assume that the subscription decisions are made before prices are set, which renders market shares effectively exogenous.

A seminal paper introducing price discrimination into the models mentioned above is Laffont, Rey, and Tirole (1998b), henceforth referred to as LRTb[4]. Among other results they show that with linear pricing, the collusive role of the access charge is reduced by the possibility of price discrimination. The reason is that similar to the case of two-part tariffs above, a higher access charge is reflected in a higher off-net price, but the building of market share is not necessarily linked to an increase in the access deficit, since customers can be attracted by lowering the on-net price. However, as opposed to the nondiscriminatory, nonlinear pricing case, the collusive role of a high access charge is not completely removed. Proposition 2 of LRTb states that the access charge still *locally* acts as a collusion device, which means that profits increase locally, if the access charge is increased above marginal cost.

As in the nondiscriminatory case, the corresponding result for nonlinear prices is quite different. Gans and King (2001) demonstrate that networks competing in two-part tariffs with discriminating call prices will negotiate a very *low* (below marginal cost) access charge in order to soften competition. They also conclude that the widespread "bill and keep" arrangements, corresponding to a zero access charge, may be undesirable from the consumers' perspective. As Cherdron (2000) notes, however, their result, pre-

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[4] A summary of the results of LRTa and LRTb is given in Laffont, Rey, and Tirole (1997).

dicting off-net prices below on-net prices, is somewhat at odds with what can be observed in existing mobile networks.

Summarizing the above, while under nonlinear pricing networks are either indifferent about the access charge or prefer an access charge below marginal cost, the work concerned with the linear pricing case unanimously suggests that networks will negotiate a high access charge to maximize joint profits. Subsequently, I will show that actually the opposite might be the outcome of network competition in linear prices, and networks might well make use of a reciprocal access charge *below* marginal cost. This result may look similar to the one of Gans and King (2001), but there is an important difference. While their result has been criticized for being out of line with observed price structures, this does not apply to my findings, at least in the linear pricing case. Access might be sold at a discount, but off-net prices still exceed on-net prices in equilibrium. Moreover, there turns out to be little scope for regulatory intervention against "bill and keep" arrangements. These arrangements might result from collusion, but then they are also welfare improving compared with cost-based access pricing. However, for competition in two-part tariffs, the Gans and King (2001) result is confirmed if receivers' utility is taken into account. The negotiated access charge is always below marginal cost, and off-net calls are cheaper than on-net calls.

2.3 Introducing Call Externalities

All of the papers discussed above share the basic assumption that a call generates utility only for the caller and not for the receiver. In this paper I divert from this assumption by introducing *call externalities*. The obvious point that a call generates utility also for the receiver has been recognized[5], but nonetheless widely neglected in the literature. Only recently, and independently from this work, Kim and Lim (2001), and Jeon, Laffont, and Tirole (2002) have come up with similar models incorporating a call externality. However, they study a "receiver pays" system, where both the caller and the receiver of a call are charged. Note that the receiver of a phone call incurs the opportunity costs of the time the call takes. Hence he must get some strictly positive utility from a call, otherwise he would not answer the call. On the other hand it might be argued that at least on average the utility of the receiver will be smaller than the utility of the caller. Whatever the "real" average magnitude of receivers' utility, neglecting it is likely to introduce a relevant distortion in the analysis of network competition.

First, however, it can be seen that under nondiscriminatory pricing the analysis of competition remains unchanged[6]. It is clear that volume demand is independent of any call externality. Obviously, nondiscriminating prices

[5] DeGraba (2000) suggests that the total utility generated by a call is shared equally between the calling parties. See also the discussion in Hahn (2001).

[6] See also the discussion in Schiff (2001).

also make the subscription decision independent of receivers' utility. Hence neither subscription nor volume demand or profits are influenced by the level of passive utility. This means that the results derived from the standard model of nondiscriminatory pricing discussed above carry over to the extension we study here. The only deviation from LRTa's model arises in the judgement of welfare implications. Indeed, neglecting the call externality underestimates social welfare. To implement the social optimum, the price of a call would have to be below marginal cost.

Volume demand stays of course independent of the call externality also with termination-based price discrimination, but the subscription decision is influenced if on-net prices differ from off-net prices. This is because the utility from receiving calls contributes to the positive network externality under on-net prices (say) below off-net prices. An increase in a network's market share raises the number of calls received by (and hence benefits the) subscribers of this network. In their subscription decision, consumers compare the net utilities they receive from joining either network. If a network raises its off-net price, this has two effects. First, the net utility of this network's customers decreases, and second, since these customers' demand for off-net calls falls, also the rival network's customers suffer, because they less frequently enjoy the benefit of being called. This second effect lowers customers' incentives to switch to the rival network. As the access charge, the call externality is reflected in equilibrium prices, which determine profits. Indeed, if the utility of receiving calls is sufficiently high, the second effect explained above becomes so strong that networks will prefer an access *discount* in order to keep the resulting off-net prices below the monopoly price.

This analysis rests on the assumption that profits are directly determined only by prices. Note, however, that in the case of two-part tariffs profits also depend on the fixed charge. As mentioned above, this has a deep impact on the nature of competition. The case of termination-based price discrimination with two-part tariffs is analyzed in chapter 5.2 of Jeon, Laffont, and Tirole (2002). Although their work is devoted to the receiver pays system, they include a short study of their model in the absence of reception charge, which of course coincides with a caller pays system. Interestingly, they show that if receivers' utility is high enough (equal to callers' utility), then for any given level of the access charge, the price for off-net calls in a symmetric equilibrium becomes infinite, resulting in *connectivity breakdown*. The intuition for this is the following. Any off-net call made generates utility for the caller and the receiver. However, since only the caller pays for the call, if receivers' utility is high, net surplus is higher for the receiver than for the caller. This means that while raising the off-net price may decrease the direct profit from off-net calls, at the same time it makes the own network more attractive, resulting in an increase in market share. The total effect on profit becomes positive, if receivers' utility is high. Furthermore, if receivers' utility is high enough, the total effect on profit is positive *regardless of the level of the off-net price*. This, of course, means that the only equilibrium has an infinite off-net price.

We conclude that the introduction of call externalities has a strong impact on the outcome of competition in the case of termination-based price discrimination. This is the case I study for the remainder of this paper.

3 The Model

In this section I introduce the model. It is based on the model of LRTb, but for simplicity I neglect fixed costs (which does not change the results qualitatively). On the other hand, I extend the model by adding the call externality.

3.1 Cost and Price Structure

Imagine a market with two networks labeled 1 and 2. Both networks have full coverage. The marginal cost of originating or terminating a call is $c_0 > 0$, and the total marginal cost of a call is $c = 2c_0 + c_1$, where $c_1 \geq 0$ is the marginal cost of transmitting a call from the originating to the terminating end. The reciprocal unit access charge is $a \geq -(c_0 + c_1)$[7]. Networks either compete in linear prices p_{ii} (for on-net calls within network i) and p_{ij} (for off-net calls originating in network i and terminating in network j), or, in the case of two-part tariffs, also in the fixed charge F_i.

3.2 Subscription Decision and Demand

On the demand side there is a large number of consumers. A consumer can be member of at most one network. From the consumers' point of view the networks are horizontally differentiated as in Hotelling's model. The networks are located at the extreme points of the unit interval $[0, 1]$, and each consumer is located at some address $x \in [0, 1]$. The total number of consumers, normalized to 1, is distributed uniformly on this interval. The degree of horizontal differentiation is measured by a parameter t corresponding to the "transport costs". A consumer located at x faces a disutility of $t|x - x_i|$ if he subscribes to network i, where $x_1 = 0$ and $x_2 = 1$ are the locations of the two networks.

Consumers have homogeneous preferences for calls to other consumers. Calls to different consumers constitute independent goods and total utility is additively separable. The utility from an active call of length q is given by

[7] A negative access charge corresponds to subsidising termination. The subsidy cannot be larger than the costs of originating and transmitting a call, however, since otherwise a network could make profits by installing a computer which permanently calls into the rival network.

$u(q)$, where $u' > 0$ and $u'' < 0$.[8] Consumers also get utility from receiving calls. We denote the utility of receiving a call (*passive utility*) of length q by a strictly increasing and strictly concave function $\bar{u}(q)$.

A consumer with income y, subscribed to network i and located at x, making a call of length q_{out} to some other consumer and receiving a call of length q_{in} from some consumer[9], enjoys a total utility of

$$\nu_0 + y + u(q_{out}) + \bar{u}(q_{in}) - t|x - x_i|,$$

where ν_0 is some fixed surplus from being connected, large enough to guarantee full participation, i.e. to prevent consumers from not subscribing in equilibrium.

The timing is as follows. First, networks cooperatively choose a reciprocal access charge, then they (noncooperatively) set on- and off-net prices, and the fixed charge, in case of two-part tariffs. Consumers choose a network to subscribe to and then they choose the length of their on- and off-net calls.

Let $q(p) = \text{argmax}_q\{u(q) - pq\}$ be the consumer's demand, writing q_{ij} short for the demand for on- and off-net calls $q(p_{ij})$. Denoting by $\nu(p) = \max_q\{u(q) - pq\}$ net surplus, under price discrimination with given market shares α_1 and α_2, network i offers its subscribers a total net surplus of[10]

$$w_i = \alpha_i[\nu(p_{ii}) + \bar{u}(q_{ii})] + \alpha_j[\nu(p_{ij}) + \bar{u}(q_{ji})] - F_i.$$

Letting $h_{ij} = \nu(p_{ij}) + \bar{u}(q_{ji})$, we may write

$$w_i = \alpha_i h_{ii} + \alpha_j h_{ij} - F_i. \tag{1}$$

4 Existence and Stability of Equilibria

4.1 Existence of Consumer Equilibria

For fixed prices, a *consumer equilibrium* is given if the market shares are such that no consumer has an incentive to unilaterally switch to the other network. If the market is cornered, i.e. if $\alpha_i = 1$ for some i, then even the consumer with the weakest preferences for network i (the consumer located at x_j) chooses to subscribe to this network. On the other hand, if there is a shared market equilibrium with $0 < \alpha_i < 1$, then the consumer located at $x = \alpha_1$ is indifferent between the networks. The market share $\alpha_1 = \alpha$ (and

[8] For technical reasons I assume additionally that the Inada conditions $u'(0) = \infty$ and $u'(\infty) = 0$ are fulfilled, guaranteeing strictly positive and finite demand for all positive prices.

[9] One could imagine that each consumer makes exactly one call to each other consumer, and only the length of a call is variable.

[10] Throughout this article let $j = 3 - i$, if it appears on only one side of an equation.

$\alpha_2 = 1-\alpha$) in a shared market equilibrium can thus be calculated from the indifference condition

$$w_1 - t\alpha = w_2 - t(1-\alpha),$$

and reads

$$\alpha = \frac{1}{2} + \sigma(w_1 - w_2),$$

where $\sigma = 1/2t$ measures the substitutability between the two networks. Inserting from (1), setting $\alpha = \alpha_1 = 1 - \alpha_2$ and solving for α yields

$$\alpha = \frac{H_1}{H_1 + H_2}, \tag{2}$$

with $H_i = 1/2 + \sigma(h_{ij} - h_{jj} + F_j - F_i)$. For a shared market equilibrium to exist, H_1 and H_2 must have the same sign: $H_1 H_2 > 0$.

4.2 Stability of Consumer Equilibria

In general, there may be multiple consumer equilibria for given prices. However, some of these can usually be eliminated by pointing out that an economically meaningful equilibrium has to be *stable* with respect to an appropriate adjustment dynamic. Following the analysis in LRTb, we conclude that generically there are either three consumer equilibria (the two cornered market outcomes and an unstable shared market equilibrium), if both H_1 and H_2 are negative, or a unique, stable consumer equilibrium, which is a cornered market one if $H_1 H_2 < 0$, and a shared market equilibrium if H_1 and H_2 are positive.

4.3 Network Equilibrium

Imagine prices and the fixed charge are fixed and a corresponding stable consumer equilibrium has been realized. If in this situation neither network can gain by unilaterally changing its prices or fixed charge (taking into account the dependence of consumer equilibria on these values), then these values constitute what we call a *network equilibrium.* For the remainder of this paper I concentrate on *symmetric* network equilibria.

5 Part I: Linear Pricing

First we examine the case of linear pricing, which means that networks are not allowed to use a fixed charge. So in this section let $F_1 = F_2 \equiv 0$.

5.1 Necessary Conditions for Symmetric Network Equilibria

Turning to the networks' pricing decisions, we first derive the profit functions. For given prices and a corresponding stable consumer equilibrium α, profit of network 1 is given by

$$\pi_1 = \alpha^2(p_{11} - c)q_{11} + \alpha(1-\alpha)(p_{12} - c)q_{12} + (a - c_0)(q_{21} - q_{12}),$$

and an analogous equation holds for π_2. If we write

$$M_{ij} = [p_{ij} - c(1+m)]q_{ij} + mcq_{ji}$$

for the *unit profit* of network i (the profit a single customer of network i generates with one active call to and one passive call from network j), denoting by $m = (a - c_0)/c > -1$ the (relative) markup on access, profit of network i can also be written in the form

$$\pi_1 = \alpha^2 M_{11} + \alpha(1-\alpha)M_{12}.$$

Taking into account that M_{ii} depends only on p_{ii}, the first order conditions for a shared market equilibrium are given by

$$\frac{\partial \pi_1}{\partial p_{11}} = 2\alpha \frac{\partial \alpha}{\partial p_{11}} M_{11} + \alpha^2 \frac{\partial M_{11}}{\partial p_{11}} + \frac{\partial \alpha}{\partial p_{11}}(1-2\alpha)M_{12} = 0,$$
$$\frac{\partial \pi_1}{\partial p_{12}} = 2\alpha \frac{\partial \alpha}{\partial p_{12}} M_{11} + \alpha(1-\alpha) \frac{\partial M_{12}}{\partial p_{12}} + \frac{\partial \alpha}{\partial p_{12}}(1-2\alpha)M_{12} = 0,$$

and the respective equations for network 2.

Looking for a symmetric shared market equilibrium, where $p_{11} = p_{22}$, $p_{12} = p_{21}$, and $\alpha = 1/2$, the first order conditions for network 1 read

$$\frac{\partial \alpha}{\partial p_{11}} M_{11} + \frac{1}{4}\frac{\partial M_{11}}{\partial p_{11}} = 0,$$
$$\frac{\partial \alpha}{\partial p_{12}} M_{11} + \frac{1}{4}\frac{\partial M_{12}}{\partial p_{12}} = 0.$$

Inserting from (2), rearranging terms, and with a little abuse of notation treating $\bar{u}(q_{ij})$ as an indirect utility function $\bar{u}(q(p_{ij}))$ of p_{ij}, we get

$$\frac{\partial M_{12}}{\partial p_{12}} = \frac{\partial M_{11}}{\partial p_{11}} \frac{(\nu' - \bar{u}')(p_{12})}{(\nu' + \bar{u}')(p_{11})}, \tag{3}$$

$$\frac{\partial M_{11}}{\partial p_{11}} = -\sigma M_{11} \frac{(\nu' + \bar{u}')(p_{11})}{H_1}. \tag{4}$$

What can we infer from these equations about the prices in a stable shared market equilibrium? First, note that M_{11}, the simple unit profit $(p_{11} - c)q_{11}$, is positive for $p_{11} > c$, and upward sloping for $p_{11} < p^M$, where p^M denotes the monopoly price (for marginal cost c)

$$p^M = \mathrm{argmax}_p\{(p-c)q(p)\}.$$

We also know that $\nu' + \bar{u}' < 0$ and that H_1 must be positive for the shared market equilibrium to be stable. From (4) then follows that the unit profit $M_{11}(p_{11})$ has the same sign as its derivative. Hence, necessarily, $c < p_{11} < p^M$. In this sense the equilibrium on-net price is "well-behaved". This need not be the case for the off-net price. As equation (3) suggests, the sign of $\partial M_{12}/\partial p_{12}$ depends on the sign of $\nu' - \bar{u}'$, which may well be positive if marginal passive utility is high.

5.2 Constant Elasticity of Demand

To be a bit more specific, I use the explicit utility function

$$u(q) = \frac{q^{1-1/\eta}}{1-1/\eta}, \qquad \eta > 1,$$

from LRTb, which yields the constant elasticity demand function[11] $q(p) = p^{-\eta}$, indirect utility $u(q(p)) = \frac{\eta}{\eta-1}p^{1-\eta}$, net surplus $\nu(p) = \frac{1}{\eta-1}p^{1-\eta}$, and a monopoly price of $p^M = \frac{\eta c}{\eta-1}$.

Furthermore, I assume that the utility from passive calls is a fixed fraction β of the utility from active calls,

$$\bar{u}(q) = \beta u(q), \text{ with } 0 \leq \beta < 1.$$

With these specifications, the first order conditions for network 1 can be expressed by the following two equations.

$$p_{12}^{-1} = \frac{1}{1+m}\left(\frac{1}{p^M}\frac{2\beta\eta}{1+\beta\eta} + \frac{1-\beta\eta}{1+\beta\eta}p_{11}^{-1}\right), \tag{5}$$

$$p_{12}^{-1} = \left[\frac{p^M}{\eta(p^M - p_{11})p_{11}^{\eta-1}} - \frac{\eta-1}{2\sigma(1+\beta\eta)}\right]^{\frac{1}{\eta-1}}. \tag{6}$$

I have intentionally written these equations so as to describe the reciprocal value of the off-net price as a function of the reciprocal value of the on-net price. This allows me to draw the graphs of the two functions, as is done in Figure 1, and find all symmetric candidate equilibria as points of intersection of the corresponding curves.

Let us first have a closer look at (5). The right hand side of this equation is an affine linear function of p_{11}^{-1}, which depends on the parameters m, η, and β, but not on σ. Its slope decreases with β, falling from $(1+m)^{-1}$ for $\beta = 0$ to zero for $\beta = 1/\eta$ and approaching $-(1+m)^{-1}$ for $\beta \to \infty$. At the monopoly price $p_{11} = p^M$, we have

$$p_{12}^{-1} = \frac{1}{1+m}\frac{2\beta\eta + 1 - \beta\eta}{(1+\beta\eta)p^M} = \frac{1}{(1+m)p^M},$$

[11] This is useful for deriving the quantitative results presented later on. However, by continuity these results continue to hold *qualitatively*, if we depart from the CED assumption.

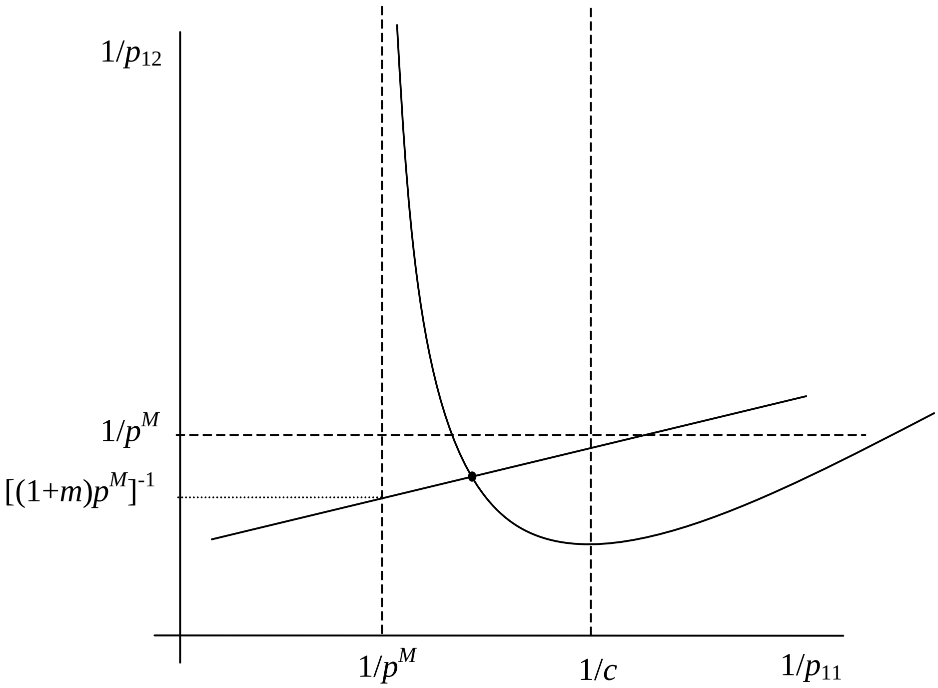

Fig. 1 The line given by (5) and the curve given by (6). Here, $\beta\eta < 1$ and $m > 0$.

which is independent of β. Graphically this means that by increasing the relative importance of passive utility, the line in the p_{11}^{-1}- p_{12}^{-1}-plane given by (5) is rotated clockwisely around the point $\left(\frac{1}{p^M}, \frac{1}{(1+m)p^M}\right)$. Note that without passive utility (i.e. for $\beta = 0$) equation (5) reduces to

$$p_{12} = (1 + m)p_{11},$$

the *proportionality rule* from LRTb. For $\beta\eta = 1$, we get $\nu'(p) \equiv \bar{u}'(q(p))$, that is, marginal net surplus of a network's own customers equals marginal passive utility of the rival's customers for any level of the off-net price. In this case varying the off-net price has no influence on the market shares, since the positive and the negative effect exactly cancel out. Then it is clearly optimal for the network to set the off-net price to its monopoly level, $p_{12} = (1 + m)p^M$. This is reflected by the line (5) becoming a horizontal at this value for $\beta\eta = 1$.

Turning to (6), we can see that this equation does not involve a, the access charge. For $\eta > 2$, the right hand side of (6) is defined only if the expression in square brackets is nonnegative. The second term of this expression is a negative constant, it does not depend on p_{11}. The first term is positive for $p_{11} < p^M$ and – viewed as a function of p_{11}^{-1} – downward sloping from its vertical asymptote $\{p_{11} = p^M\}$ to its minimum at $p_{11} = c$. For

$p_{11}^{-1} > c^{-1}$ the function given by (6) is strictly increasing and unbounded, its slope converging to $\eta^{-1/(\eta-1)}$ for $p_{11}^{-1} \to \infty$. Furthermore, this function is convex at least for values of p_{11} slightly below p^M. The second term in square brackets shifts the curve up (for $\sigma \to \infty$) or down (for $\sigma \to 0$).

As noted, (6) has a negative slope in the relevant region $c < p_{11} < p^M$. Hence there exists at most one point of intersection with (5) in this region, if the slope of this line is nonnegative, i.e. if $\beta\eta \leq 1$. If β exceeds $1/\eta$, the slope of (5) is negative, and there may exist two points of intersection). However, the second point will be outside the relevant region if σ is small.

5.3 Second Order Conditions

The next proposition establishes the existence of a unique, stable, symmetric equilibrium for low substitutability.

Proposition 1 *If σ is small enough, there exists a unique, stable, symmetric equilibrium. Its price constellation is given by the intersection of (5) and the downward sloping part of (6).*

Proof Consider the case $\sigma = 0$. Then the networks are monopolies and the prices are at their respective monopoly levels. Graphically, (6) degenerates to a vertical line at $p_{11} = p^M$, intersecting (5) in $p_{12} = (1+m)p^M$. This symmetric candidate equilibrium is thus unique and stable (since $H_i = 1/2 > 0$). Moreover, the market shares are constant for $\sigma = 0$. Hence, given the candidate equilibrium values of p_{22} and p_{21}, network 1's profit is

$$\pi_1(p_{11}, p_{12}) = \frac{1}{4}[(p_{11} - c)q_{11} + (p_{12} - c(1+m))q_{12} + mcq_{21}].$$

This function is quasi-concave in (p_{11}, p_{12}), hence $(p^M, (1+m)p^M)$ is its unique maximum. For positive values of σ the slope of (6) becomes finite, this means that the candidate equilibrium on-net price falls below the monopoly price. The candidate equilibrium remains unique for small values of σ, and by continuity of H_i in σ it remains stable. Also, by continuity of the market share in prices and in σ, network 1's profit function remains quasi-concave. Hence the second order conditions are fulfilled for low substitutability. □

This proof is similar to the proof of Proposition 1 in LRTb. The result is slightly different, however, in the sense that the call externality prevents the existence of equilibrium in the case of high substitutability, even for $a = c_0$. For example, if $a = c_0$ (i.e. $m = 0$) and $t = 0$ (i.e. $\sigma = \infty$), the curve given by (6) admits its minimum at $p_{11} = p_{12} = c$. For any positive value of β, however, (5) yields $p_{12} > c$ at $p_{11} = c$, and hence there is no point of intersection in the relevant region for large enough values of σ.

5.4 Equilibrium Analysis

From now on I concentrate on the case where substitutability is low enough to guarantee existence of a unique stable equilibrium. We then ask, in which way the equilibrium depends on the various parameters of the model.

5.4.1 Comparative Statics The next lemma shows that while the on-net price always decreases with the substitutability parameter σ, the direction of movement of the off-net price depends on the strength of the call externality and on the elasticity of demand. On the other hand, an increase in the access charge always lowers the on-net price and raises the off-net price.

Lemma 1 *For $\sigma > 0$ and $\beta \geq 0$, the symmetric equilibrium prices given by (5) and (6) are such that*
(i) The on-net price decreases with σ and the off-net price decreases with σ if $\beta\eta < 1$, increases with σ if $\beta\eta > 1$, and is constant at $p_{12} = (1+m)p^M$ if $\beta\eta = 1$.
(ii) The on-net price decreases in a, while the off-net price increases in a.

Proof An increase in σ shifts the graph of (6) upwards and does not influence the graph of (5). The point of intersection thus moves to the right, i.e. p_{11}^{-1} increases. The vertical direction of movement depends on the slope of (5). If $\beta\eta < 1$ (this includes the LRTb case $\beta = 0$), the slope is positive, so also p_{12}^{-1} increases. If $\beta\eta > 1$ the slope is negative and the intersection point moves down, and if $\beta\eta = 1$ the line is horizontal at $p_{12}^{-1} = [(1+m)p^M]^{-1}$. Increasing a or, equivalently, m, shifts the line (5) downwards. Since (6) slopes downward in the relevant region, the point of intersection moves down and to the right. This means p_{11} falls and p_{12} rises. □

In contrast to the result in LRTb, more substitutability exerts upward pressure on the off-net price, if β is large enough. Intuitively, if the call externality-induced negative effect of an increasing off-net price on the rival's customers is large, higher substitutability creates incentives for the networks to exploit this effect and raise the off-net price while lowering the on-net price to compensate their own customers.

Remark Part (ii) of the lemma appears to contradict the corresponding result of LRTb, since the case of no call externality is not excluded. LRTb (p. 48) state that the off-net price may *decrease* in a if σ is not small enough. In their proof they give a numerical example for this phenomenon. However, the values they provide ($\eta = 2$ and $\sigma = c = m = 1$) lead to the candidate equilibrium prices $p_{11} = 1 = c$ and $p_{12} = 2$. A small increase in a then does indeed decrease the off-net price, but simultaneously the on-net price falls below marginal cost and, as noted above, in this region any candidate equilibrium is *unstable* and will therefore never be realized. In the region $c < p_{11} < p^M$, where the consumer equilibrium is stable, (6) is strictly decreasing and hence the off-net price inevitably rises with the access charge.

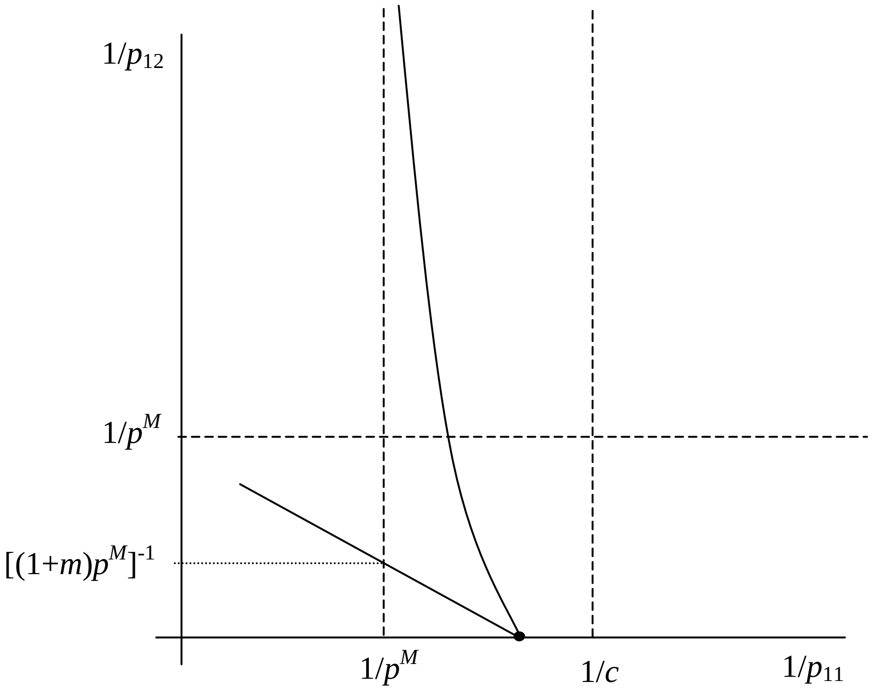

Fig. 2 If $\beta\eta > 1$, connectivity breakdown may occur for a high access charge.

5.4.2 Connectivity Breakdown For small $\sigma > 0$ the curve (6) cuts the $1/p_{11}$-axis, and the smaller σ, the closer the intersection point lies to $p_{11} = p^M$. If $\beta\eta > 1$, the slope of the line (5) is negative. Hence, by increasing m we can shift the line down until it intersects the curve exactly at the $1/p_{11}$-axis (see Figure 2). Thus we have an equilibrium with $1/p_{12} = 0$, or $p_{12} = \infty$. This proves the following lemma.

Lemma 2 *For small $\sigma > 0$ and $\beta\eta > 1$ there exists $\bar{a}$, such that for $a \to \bar{a}$ from below, $p_{12} \to \infty$. The threshold $\bar{a}$ approaches infinity, if σ goes to 0 or $\beta\eta$ falls to 1.*

This is the case of *connectivity breakdown*, which has already been observed by Jeon, Laffont, and Tirole (2002) for the case of two-part tariffs. The intuition is the same as in their case. If $\beta\eta > 1$, then any off-net call benefits the receiver more than the caller. Raising the off-net price makes the difference in net surplus smaller and hence increases the network's market share. If a is large enough, then this increase in market share more than offsets the corresponding loss in direct profit from off-net calls *for all levels of the off-net price.* Hence it is optimal for the network to deter any off-net call by raising its price to infinity.

5.5 The Collusive Role of the Access Charge

Part (ii) of Lemma 1 states that varying the access charge results in the equilibrium prices moving in opposite directions. We know that the equilibrium on-net price is always below the monopoly price. If this is also the case for the off-net price, the impact on profits of varying the access charge is ambiguous. If, however, the off-net price is above the monopoly price, both prices will move towards the monopoly price (and hence raise profits) only if the access charge is lowered. Imagine $\beta\eta > 1$. This is not an unrealistic case, since $\eta > 1$ and β may well be only slightly below 1. The slope of (5) is then negative, and for $\sigma > 0$ we have $p_{12} > (1+m)p^M$ in equilibrium.[12] Now let the access charge equal marginal termination cost, so $m = 0$. Then the off-net price exceeds the monopoly price, and we have the situation described above. In order to maximize equilibrium profits, both networks will negotiate an access charge a below c_0.

If $\beta\eta = 1$, the equilibrium off-net price is $(1+m)p^M$, independently of σ. For $a = c_0$ then p_{12} is at the monopoly level, while p_{11} is below p^M. Starting from these values, a small decrease in a raises p_{11} towards the monopoly price and thereby has a positive first-order effect on profits from on-net calls, but only a second-order (negative) effect on profits from off-net calls. In sum, profits rise. By continuity this continues to hold if $\beta\eta$ is not too far below 1. This shows that networks may prefer an access discount even for $\beta\eta < 1$. For very low values of β, of course, this need not be the case.

Graphically, this can easily be seen if we keep in mind that since (6) is independent from the access charge, networks can only shift the line (5) up or down by varying the access charge. Thereby they can select any point on (6), subject to the restriction $m > -1$. Maximizing profits, they will choose the point where their isoprofit curve is tangent to (6). The point of tangency is unique, at least if σ is not too large, since (6) is convex in the vicinity of $p_{11} = p^M$ and the equilibrium profit function is quasi-concave in equilibrium prices (the upper-contour sets of the isoprofit curves are convex), peaking at the "monopoly point" $(1/p^M, 1/p^M)$. It follows immediately that the tangency point will lie northeast from the monopoly point, as illustrated in Figure 3. This means that with the negotiated profit-maximizing access charge, both on- and off-net prices are smaller than the monopoly price. If the slope of (5) is negative or only slightly positive, of course, this implies that this line intersects $\{p_{11} = p^M\}$ above the monopoly point. Hence $[(1+m)p^M]^{-1} > (p^M)^{-1}$, or $m < 0$. This analysis proves the first part of the next proposition.

Proposition 2 *Fix $\sigma > 0$ small enough. There exists $0 < k < 1$ such that if $\beta\eta > k$, networks will agree on an access discount, if $\beta\eta < k$, networks will negotiate an access markup, and if $\beta\eta = k$, networks will agree on $a = c_0$.*

[12] For $\sigma = 0$ the market consist of two separate monopolies and the optimality of $p_{ii} = p_{ij} = p^M$ implies that networks will prefer $m = 0$ ($a = c_0$).

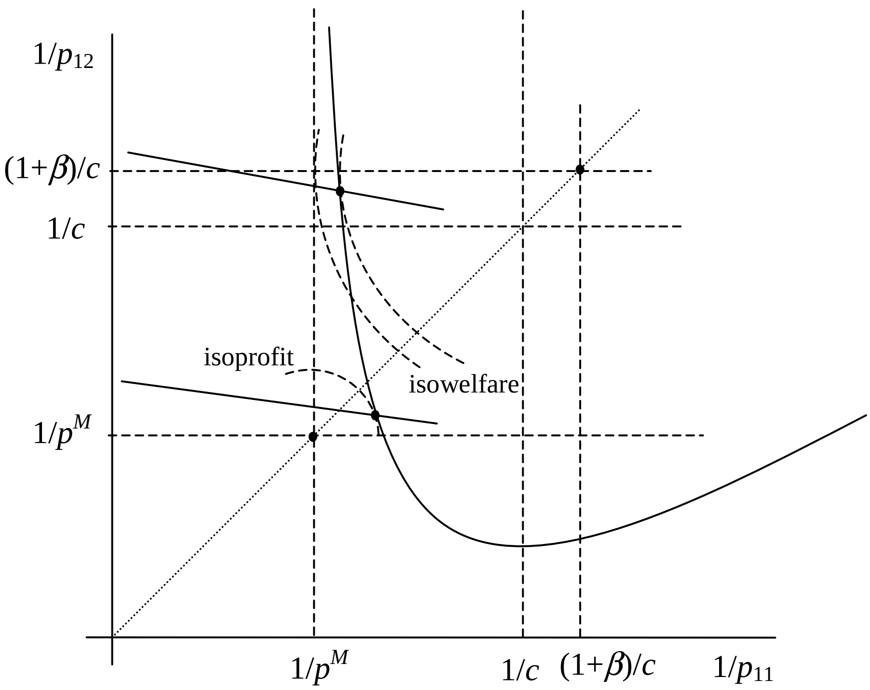

Fig. 3 Tangency points between (6) and the isoprofit respectively isowelfare curves. For small σ, the welfare maximizing choice of a is below the profit maximizing one, which in turn is below c_0 if β is not too small.

Remark The case $\beta = 0$ is the case without passive utility, and I could in principle just refer to Proposition 2 of LRTb. In this proposition they state that for small $\sigma > 0$ (and for $\beta = 0$) the profit maximizing access charge exceeds c_0. While this statement turns out to be true, unfortunately their proof is flawed[13], so I give the correct proof here.

Proof It suffices to show that networks will negotiate a markup on access if $\beta = 0$. Given the analysis in the last paragraph, the second and third part of this proposition then follow immediately from continuity of the negotiated access charge in $\beta\eta$ and from the intermediate value theorem, respectively. Note, that for $a = c_0$ and $\beta = 0$, the line (5) is the diagonal $\{p_{12} = p_{11}\}$. By symmetry of the equilibrium profit function in p_{11} and p_{12}, the slope of the isoprofit curves is equal to -1 all along the diagonal. The slope of (6) at the

[13] In their proof, LRTb (p. 49) argue that for small $\sigma > 0$ their *Lemma 2 shows that both on-net and off-net prices increase with the access charge.* From this they infer that *starting from $a = c_0$, a small increase in the access charge raises both prices toward the monopoly level and therefore leads to higher profits.* However, actually their Lemma 2 (correctly) states that for small $\sigma > 0$ the on-net price *decreases* in a. Hence it is not obvious that an increase in a does indeed raise profits.

intersection with the diagonal, on the other hand, converges to $-\infty$ as the point of intersection approaches the monopoly point, i.e. if $\sigma \to 0$. Thus, for small σ the point of tangency is below the diagonal (see Figure 3), where $p_{11} < p_{12}$, and by the proportionality rule (recall that we are considering $\beta = 0$ here), $m > 0$, i.e. a markup on access, is a necessary condition for this. □

Note that the last sentence of this proof also establishes that for small σ, the profit maximizing point of tangency lies below the diagonal. Since networks will choose the access charge to let this point become an equilibrium, we obtain the following corollary:

Corollary 1 *If σ is positive but small and networks may cooperatively determine the access charge, then the resulting equilibrium prices will show a markup on off-net calls.*

5.6 Welfare and the Socially Optimal Access Charge

From the social viewpoint, the optimal access charge is the access charge that maximizes welfare, the sum of profits and consumer surplus, in equilibrium:

$$W(p_{11}, p_{12}) = \frac{1}{2}[(1+\beta)u(q_{11}) - cq_{11} + (1+\beta)u(q_{12}) - cq_{12}]. \tag{7}$$

The unconstrained welfare maximizing choice of prices would yield prices strictly below marginal cost for $\beta > 0$. This is due to the call externality, which is not internalized by the calling party when choosing volume demand. To maximize welfare, the caller must be induced to extend the length (or frequency) of his calls up to the point where marginal *total* utility created equals marginal cost. This means $(1+\beta)u'(q_{ij}) = c$ and is induced by a price of $p_{ij} = (1+\beta)^{-1}c$. Of course these prices cannot be sustained in an equilibrium, since then profits are negative.

Assume a benevolent regulator can set an arbitrary access charge subject to the technical constraint $a > -c_0 - c_1$. By symmetry, the iso-welfare curves surrounding the unconstrained optimum have a slope of -1 along the diagonal $\{p_{11} = p_{12}\}$. Since the slope of (6) at the intersection with the diagonal is smaller than -1 for small σ, we can conclude that for small σ the point of tangency of (6) and the iso-welfare curves lies above the diagonal, and therefore also above the profit maximizing point on (6), as shown in Figure 3. This means that the welfare maximizing access charge is below marginal cost and also below the profit-maximizing access charge. Moreover, I can show that the welfare maximizing access charge might actually fall below zero. It follows from the additively separable form of (7) that the iso-welfare curves have vertical tangents at $p_{12} = c(1+\beta)^{-1}$. Since (6) is a vertical line at $p_{11} = p^M$ for $\sigma = 0$, the point of tangency approaches

$(1/p^M, (1+\beta)/c)$ as $\sigma \to 0$. Denoting the socially optimal access charge by a^w, this implies that $(1 + \frac{a^w - c_0}{c})p^M$ converges to $\frac{c}{1+\beta}$, or

$$a^w \to c_0 \left(1 - \frac{c}{c_0} \frac{1+\beta\eta}{\eta + \beta\eta}\right).$$

It can be seen that the sign of a^w depends on the relative size of β and η. Note that $c \geq 2c_0$ and for $\beta = 1$ the second factor in brackets is $\frac{1+\eta}{2\eta} > \frac{1}{2}$. Thus the expression in brackets is negative, and so is a^w. Similarly, if $\eta \leq 2$, then the second factor in brackets exceeds $1/2$ for any positive β, and again $a^w < 0$. The profit maximizing access charge a^π, on the other hand, is always positive for small $\sigma > 0$. We summarize this as follows.

Proposition 3
(i) $a^w < c_0$ *for small* σ.
(ii) If $\frac{c}{c_0} \frac{1+\beta\eta}{\eta+\beta\eta} > 1$, *then* $a^w < 0 < a^\pi$ *for small* σ. *This includes the cases* $\beta = 1$ *or* $\eta \leq 2$.
(iii) If $\frac{c}{c_0} \frac{1+\beta\eta}{\eta+\beta\eta} < 1$, *then* $0 < a^w < a^\pi$ *for small* σ.

The more realistic of the cases (ii) and (iii) of this proposition seems to be (ii), since it follows from $\eta < 2$. Note that in this case networks may actually agree on a "bill and keep" arrangement, which sets $a = 0$. This might result from the consideration that in existing mobile phone networks, "bill and keep" helps to save transaction costs of interconnection, a point not included in my model. If transaction costs are substantial and were taken into account, "bill and keep" might indeed turn out to be profit maximizing. Note, however, that contrary to the view of Gans and King (2001), from Proposition 3(ii) it follows that "bill and keep" is welfare improving compared with cost-based access pricing.

In our model a higher level of substitutability may even lead to a perfect alignment of networks' and the regulator's objectives. If the slope of (6) at the intersection point with the diagonal equals -1, then, provided equilibrium still exists, this point maximizes profits and welfare simultaneously, and the corresponding access charges coincide. For even larger values of σ, the order of these access charges will be reversed.

6 Part II: Nonlinear Pricing

In this section we examine the collusive role of the access charge under nonlinear pricing, which here means competition in two-part tariffs. The profit equation for network 1 becomes

$$\pi_1 = \alpha^2(p_{11} - c)q_{11} + \alpha(1-\alpha)(p_{12} - c)q_{12} + (a - c_0)(q_{21} - q_{12}) + \alpha F_1.$$

As usual when competing in two-part tariffs, networks set prices so as to maximize social welfare, and then extract consumer surplus via the fixed charge. For the on-net price, the call externality is fully internalized by the network's pricing decision, while when setting the off-net price networks take into account the call externality induced negative impact on its market share of a low off-net price. This leads to prohibitively high off-net prices if β is large. Indeed, Jeon, Laffont, and Tirole (2002) derive the equilibrium prices[14]

$$p_{11} = c/(1+\beta), \qquad p_{12} = (1+m)c/(1-\beta). \tag{8}$$

Hence, as $\beta \to 1$, the off-net price goes to $+\infty$, resulting in connectivity breakdown.

6.1 Profit Maximizing Access Charge

In a symmetric equilibrium, differentiating profit with respect to the fixed charge yields

$$\frac{\partial \pi_1}{\partial F_1} = \frac{\partial \alpha_1}{\partial F_1}[(p_{11} - c)q_{11} + F_1] + \frac{1}{2}.$$

Using equation (2), where $H_1 + H_2$ does not depend on F_1, we can solve for the profit maximizing fixed charge and find

$$F_1 = 1/(2\sigma) - (\nu_{11} - \nu_{12}) - (\bar{u}_{11} - \bar{u}_{12}) - (p_{11} - c)q_{11}.$$

Inserting the equilibrium values of prices and the fixed charge into the profit equation and solving for the profit maximizing access charge, we finally get

$$m^\pi = -\frac{1 + 3\eta\beta}{1 + 2\eta\beta + \eta},$$

which for $0 < \beta < 1$ implies $a^\pi < c_0$. Hence, under two-part tariffs, networks will invariably negotiate an access charge below marginal cost. This collusive access charge is the smaller, the larger β is. m^π goes to -1 for $\beta \to 1$ and approaches $-1/(1+\eta)$ for $\beta \to 0$[15]. The resulting off-net price $p_{12} = \frac{c}{1+2\beta+1/\eta}$ is always below the on-net price. Note, that while the off-net price for any *given* access charge goes to infinity when passive utility gets closer and closer to active utility, this is not the case for the off-net price resulting from the collusive choice of the access charge (both the nominator and the denominator go to zero in the second equation in (8)). The intuition for this is of course that connectivity breakdown cannot be optimal for networks that are maximizing joint profits.

[14] They also show that a stable symmetric equilibrium exists, if σ is small and a is not too far from c_0.

[15] For $\beta = 0$ we get the result of Gans and King (2001). They do not use a CED function and only state that the collusive access charge is given implicitly by $q((1+m^\pi)c) = m^\pi c q'((1+m^\pi)c)$. With our CED function $q(p) = p^{-\eta}$ this is equivalent to $m^\pi = -1/(1+\eta)$.

6.2 Welfare Maximizing Access Charge

The socially optimal access charge a^w would be the one giving rise to an off-net price of $p_{12} = c/(1+\beta)$. This is achieved by the (negative) markup $m^w = -2\beta/(1+\beta)$, equivalent to

$$a^w = -\frac{2\beta c}{1+\beta} + c_0. \qquad (9)$$

It can be seen that the socially optimal access charge is below marginal cost, but always greater than the profit maximizing access charge. We summarize our findings in the following proposition.

Proposition 4 *If networks compete in two-part tariffs, then* $-c_0 - c_1 < a^\pi < a^w < c_0$.

This shows that with two-part tariffs, setting the access charge at marginal cost can never be optimal from the social viewpoint. On the contrary, from the social viewpoint, "bill and keep" may not only be an improvement over cost-based access pricing, but even optimal. (From (9), $\beta = \frac{c_0}{3c_0+2c_1}$ implies $a^w = 0$.)

7 Conclusion

I have argued that taking into account the utility of receiving calls has a strong impact on the outcome of competition between equals in the case of termination-based price discrimination. In that case, if networks are not too substitutable, I have shown that for sufficiently great levels of receivers' utility, collusion over the access charge will result in access sold at a discount, even in the linear pricing case. For the case of two-part tariffs, we derived qualitatively the same results as Gans and King (2001) do, including the anomaly of off-net prices below on-net prices. However, with linear pricing, on-net prices stay below off-net prices in equilibrium, and the socially optimal access charge may favor a "bill and keep" arrangement. In this light, recently raised concerns about networks using *high* access charges as collusion device appear unconvincing at least in the presence of termination-based price discrimination.

It might be argued that the linear pricing case is of less relevance here, because existing mobile telecommunication networks obviously do make use of two-part tariffs. The usual arguments put forward in defense of linear pricing is that the results of the standard literature on nonlinear pricing resemble that of competition in linear prices as soon as one deviates from the assumption of customer homogeneity in demand. The conjecture that this will also be the case for models of two-way interconnection is e.g. found in LRTa, LRTb, and Armstrong (1998). As mentioned in Section 2.1, Dessein (2001) has shown, in a model based on the LRTa model, that this conjecture is not true if consumers differ only in volume demand, and is even reversed if consumers differ in demand for subscription. However, this does not completely resolve the question of the real-world relevance of linear pricing, since his model excludes the possibility of termination-based price discrimination. What catches one's eye is that Dessein's (2001) second result (and the analogous result of Schiff (2002)) of collusive access charges below cost resembles our main findings. Indeed, the intuition is similar in spirit. In both cases the main difference to the LRTa model is that positive network externalities are introduced. In Dessein's (2001) model a network that lowers its price induces the market to grow, which through the network externality benefits not only this network's customers, but also the rival's. Analogously in the present model, lowering the off-net price benefits the rival's customers as well as the own customers. Therefore, in both cases, prices tend to be too high in equilibrium, which in turn induces networks to agree on a relatively low access charge to compensate these effects. This seems to indicate that combining the two mechanisms at work by allowing for customer heterogeneity in the present model would lead to an even lower cooperative access charge, a point I would like to suggest for future research.

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