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ABSTRACT

Tariff-Mediated Network Externalities: Is Regulatory Intervention Any Good?*

Mobile phone networks' practice of charging higher prices for off-net than for on-net calls has been pinpointed as the source of two competition problems: underprovision of calls and permanent disadvantages for small networks. We consider these allegations and four different remedies: limiting on/off-net differentials or off-net margins, lower termination fees, and asymmetric termination fees. In all cases a trade-off has to be made between efficiency and networks' profits on the one hand, and consumer surplus on the other. Indeed, the total welfare effects of regulating on/off-net differentials are ambiguous and depend on demand characteristics.

JEL Classification: L13, L51 and L96
Keywords: network competition, on/off-net differentials, retail price controls and termination fees

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1 Introduction

It has been alleged that mobile networks' practice of price discriminating between calls within the same network (on-net calls) and calls to other mobile networks (off-net calls) creates inefficiencies and disadvantages for small networks. The inefficiency arises from the fact that off-net calls tend to be priced far above their underlying cost, which restricts the length of calls. The disadvantage for small networks stems from tariff-mediated network externalities, which benefit networks with a large number of customers. This effect is compounded by strategic behavior based on the call externality, i.e. the utility derived from receiving calls. As a result, small networks must offer lower prices and suffer from a permanent access deficit, as shown in Hoernig (2007).

From a social planner's point of view, one could imagine two rationales for intervention. First, the inefficiency caused by high off-net call prices could raise some concerns. In this case, the main aim of intervention would be to lower off-net call prices towards the efficient level, which, taking into account the call externality, is actually below cost. The second concern of the social planner could be that small operators could exit from the market, which would harm consumers in the long run. This concern seems to make most sense when the small operator is a recent entrant, and any "protection" given to the operator will be of a temporary nature. The social planner's aim then could be to shore up the small operator's profits in order to raise its subscriber numbers.

The aim of this paper is to study four potential "remedies" which have been proposed under different circumstances: introducing caps on the on/off-net differential or the off-net margin, lowering termination fees of either both networks or only of the large network. We consider the trade-off involved between total welfare, consumer surplus and each network's profits.

Contrary to Hoernig (2007), here we only consider two-part tariffs. As is known from the literature, the effects of termination fees on networks' profits are the opposite with linear tariffs. The same holds for consumer surplus: While with two-part tariffs the competitive intensity increases with higher termination fees, it decreases with linear tariffs. Yet, it is generally accepted that two-part tariffs are a more realistic model of networks' tariff structure.

Results:

Our first result is that there is a trade-off between total welfare and consumer surplus, at least in the short run. Increasing efficiency by reducing off-net call prices also lowers the competitive intensity in the market, with networks charging higher fixed fees. This already implies that the sectoral regulator's objectives need to be precisely defined in order to decide whether intervention is warranted or not.

Imposing limits on the on/off-net differentials of both networks not only lowers the off-net price, but also increases the on-net price. That is, while one inefficiency is reduced a different one arises. We show with the help of an example that as a result "anything goes": Depending on the shape of demand and other parameters of the model, the imposition of uniform pricing or unregulated price discrimination may be optimal, or even the imposition of some intermediate limit on price discrimination.

If networks are asymmetric, then the imposition of a limit on the on/off-net differential of only the large network raises total welfare and reduces competitive intensity, increasing both networks' profits but lowering consumer surplus. Thus it is a measure that could be used in order to protect consumers in the long run, but it has costs in the short run.

Finally, the imposition of a cap on the off-net margin of the large network has the advantage of not raising its on-net price, but qualitatively its effects are similar to a limit on the on/off-net differential.

Lowering termination fees increases welfare and networks' profits but harms consumers since again competitive intensity is reduced. If networks are asymmetric, lowering only the large network's mobile-to-mobile termination fee has a smaller effect on welfare and consumer surplus, while transferring profits from the large to the small network.

Summing up, these four measures may increase efficiency and profits of small networks, but if they do this happens at the expense of consumers, at least in the short run.

Related literature:

The classic article in the literature on network competition with price discrimination between on- and off-net calls is Laffont, Rey and Tirole (1998, LRT). They consider symmetric networks and linear or two-part tariffs. Gans and King (2001) reconsidered the case of two-part tariffs and showed that networks' profits increase with lower mobile-to-mobile (M2M) termination fees.

Carter and Wright (1999, 2003) modeled the effects of asymmetry between networks on linear tariffs and the reciprocal termination fee that each would prefer. De Bijl and Peitz (2002, ch. 6.4) present the equilibrium pricing structure with two-part tariffs and tariff-mediated price discrimination. Since they do not consider a call externality, both the on-net and off-net prices are equal to their respective costs, and therefore the on/off-net differential is completely determined by the termination fee. As we will see below, if the call externality is taken into account this is no longer true.

Kim and Lim (2001) and Jeon, Laffont and Tirole (2004, JLT) introduced the modeling of the call externality, and JLT finds the profit-maximizing pricing structure with two-part tariffs. Berger (2005) considered its effect on access pricing between symmetric networks.

Hoernig (2007), contrary to the previous literature, focussed on the sources of the on/off-net differential and their implications for pricing and profits of firms. In a nutshell, larger networks will tend to set higher on/off-net differentials in equilibrium. He also showed that this differential would increase if the large network was trying to predate on the small one.

Gabrielsen and Vagstad (2008) deviate from the existing literature in that the authors assume that services are homogenous, consumers are grouped into "calling clubs" to which they place calls preferentially, and have an exogenous switching cost. They show that (at least when a pure strategy equilibrium exists) networks may want to choose a reciprocal termination fee above cost, because this increases off-net prices and competitive intensity. It is very hard to compare their results to other models, also because their model outcomes do not change continuously as the termination price approaches cost.

There is surprisingly little work available on regulatory measures that affect on/off-net price discrimination. LRT do compare uniform pricing and price discrimination under linear tariffs. They show that allowing price discrimination can enhance welfare if services are very poor substitutes, i.e. when prices are close to the monopoly price. The intuition behind their result is that for prices above the monopoly price the net surplus generated by calls is convex. This implies that the logic of their argument may be reversed once one considers prices closer to cost, where net surplus is concave rather than convex. Furthermore, they do not consider the imposition of uniform pricing under two-part tariffs, where per-minute prices close or even at cost are the norm.

Peitz (2005), to our knowledge, is the first article to investigate asymmetric termination fees under price discrimination. He finds that raising an entrant network's mobile-to-mobile termination fee slightly above cost, while maintaining the incumbent's at cost, increases the entrant's profits and consumer surplus while decreasing total welfare. While Peitz did not consider the effects of a call externality, his results are consistent with and complementary to ours.

Section 2 introduces the model, and Section 3 sets out the details of the unrestricted market equilibrium with on/off-net price discrimination. It also presents the case of predation by the large network. Section 4 discusses remedy proposals, while Section 5 concludes.

2 The Model

The following model joins elements from LRT, Carter and Wright (1999) and JLT. Two telecommunications networks are situated at the extreme points of a Hotelling line, with firm 1 at point 0, and firm 2 at point 1. Each network supports a fixed cost per client of f_i and has constant marginal costs of origination and transport of c_{0i}, and of termination of c_{ti}, with resulting on-net cost $c_i = c_{0i} + c_{ti}$. Network i receives an termination fee of a_i for terminating calls from its competitor, resulting in off-net costs $c_{fi} = c_{0i} + a_j$. Termination fees are set by a regulator. Denote the market share of network i by α_i, with $\alpha_1 + \alpha_2 = 1$, which implies that we assume that the whole market is covered in equilibrium. Firms compete in two-part tariffs and price discriminate between on-net and off-net calls. Network i's prices for on-net and off-net calls, and the fixed fee, are p_{ii}, p_{ij} and F_i, respectively, with $i, j \in \{1, 2\}$, $j \neq i$.

A mass 1 of consumers is distributed uniformly along the Hotelling line. The consumer at location x has a utility loss of $\frac{1}{2\sigma}|x - l|$ if he subscribes to the network at location l. Furthermore, similar to Carter and Wright (1999), consumers receive an additional utility $\beta = A/\sigma$ if they join network 1, where A is the *ex ante* asymmetry in market shares (before equilibrium effects). This assumption models an incumbency or reputation advantage of network 1. Its purpose is to make the market equilibrium asymmetric, with $\alpha_1 > \alpha_2$.

As in JLT consumers receive utility by making and receiving calls. The direct utility of making calls is $u(q)$, where q is the length of the call in minutes, and if the price per minute is p, the indirect utility is $v(p) = \max_q \{u(q) - pq\}$. The associated demand function is $q_{ij} = q(p_{ij})$. The utility of receiving a call of duration q is $\gamma u(q)$, where $\gamma \in [0, 1]$.

As usual, we assume a balanced calling pattern, i.e. each consumer calls each other consumer with the same probability, independent of which network they belong to. This does *not* imply that the actual traffic will be balanced, because the lengths of calls will depend on their respective prices per minute (which will differ in equilibrium).

For a consumer at location x, the utilities of subscribing to network 1 or 2 are

$$U_1(x) = w_1 + \beta - \frac{1}{2\sigma}x,\ U_2(x) = w_2 - \frac{1}{2\sigma}(1 - x) \tag{1}$$

where

$$w_i = \alpha_i \left[v\left(p_{ii}\right) + \gamma u\left(q_{ii}\right)\right] + \alpha_j \left[v\left(p_{ij}\right) + \gamma u\left(q_{ji}\right)\right] - F_i \tag{2}$$
$$= \alpha_i h_{ii} + \alpha_j h_{ij} - F_i \tag{3}$$

where $h_{ij} = v\left(p_{ij}\right) + \gamma u\left(q_{ji}\right)$. The indifferent consumer is located at $x = \alpha_1$, therefore

$$\alpha_1 = \frac{1}{2} + A + \sigma\left(w_1 - w_2\right). \tag{4}$$

This implicit equation for α_1 can be solved for

$$\alpha_1 = \frac{1/2 + A + \sigma\left(h_{12} - h_{22} - F_1 + F_2\right)}{1 + \sigma\left(h_{12} + h_{21} - h_{11} - h_{22}\right)} = \frac{H_1}{H}. \tag{5}$$

Firms' profits are described by the standard expression

$$\pi_i = \alpha_i \left[\alpha_i \left(p_{ii} - c_i\right) q_{ii} + \alpha_j \left(p_{ij} - c_{fi}\right) q_{ij} + F_i - f_i + \alpha_j \left(a_i - c_{ti}\right) q_{ji}\right], \tag{6}$$

which describes the sum of profits from on-net calls, off-net calls, subscriptions and call termination, respectively.

Consumer surplus is given by

$$CS = \int_0^{\alpha_1} U_1(x)\, dx + \int_{\alpha_1}^{1} U_2(x)\, dx = \alpha_1 \left(w_1 + \frac{A}{\sigma}\right) + \alpha_2 w_2 - \frac{\alpha_1^2 + \alpha_2^2}{4\sigma}. \tag{7}$$

Total welfare is $W = CS + \pi_1 + \pi_2$, which can be written as

$$W = \sum_{i,j=1,2} \alpha_i \alpha_j \left[(1+\gamma)\, u\left(q_{ij}\right) - c_i q_{ij}\right] + \alpha_1 \left(\frac{A}{\sigma} - f_1\right) - \alpha_2 f_2 - \frac{\alpha_1^2 + \alpha_2^2}{4\sigma}. \tag{8}$$

In particular, access profits and losses cancel out. This expression indicates the known result that, for any fixed market shares α_1 and α_2 the socially optimal prices p_{ij} are all equal to $p_{ij}^{so} = c_i / (1+\gamma)$. That is, the first-best on- and off-net prices are equal and are below cost because they internalize the call externality. This implies that the price discrimination between on- and off-net calls never leads to the firs best, and that welfare is increased whenever prices are lowered towards the efficient level. Even so, this does not imply that an imposition of uniform pricing as such will raise welfare as compared to price discrimination when applied to market prices above the efficient level, since then the equilibrium uniform price will be above the efficient level, as we show below. This is even true if termination fees are set at cost.

3 Market Outcomes

3.1 Nash Equilibrium Prices

Jeon, Laffont and Tirole (2004, p. 105) and Berger (2005) derive the profit-maximizing pricing structure. Keeping market share α_i constant, they substitute

$$F_i = \alpha_i h_{ii} + \alpha_j v(p_{ij}) - \alpha_i \gamma u(q_{ij}) + K_i \tag{9}$$

into π_i, where K_i does not depend on p_{ii} or p_{ij}. Maximizing π_i with respect to these variables then leads to

$$p_{ii}^{PD} = \frac{c_i}{1+\gamma},\ p_{ij}^{PD} = \frac{c_{fi}}{1-\gamma\alpha_i/\alpha_j} \text{ if } \alpha_i < \frac{1}{1+\gamma},\ p_{ij} = \infty \text{ otherwise.} \tag{10}$$

On-net prices internalize receivers' utility of receiving calls, leading to the efficient price below marginal cost. On the other hand, off-net prices remain above marginal cost and increase in own market share (towards infinity as α_i approaches $1/(1+\gamma)$, while the Nash equilibrium still exists).[1] Again, the higher off-net price reduces the rival network's attractiveness through limiting the number of call minutes its customers will receive, as discussed in Hoernig (2007).

The equilibrium fixed fee is

$$F_i = f_i + \alpha_i \frac{H}{\sigma} - 2\alpha_i (p_{ii} - c_i) q_{ii} + (\alpha_i - \alpha_j)\left[(p_{ij} - c_{fi}) q_{ij} + (a_i - c_{ti}) q_{ji}\right]. \tag{11}$$

It increases in α_i at $\alpha_i = \frac{1}{2}$, therefore at least for similar market shares the fixed fee is larger for the large firm. In a symmetric equilibrium, fixed fees are equal to

$$F_i = f_i + \frac{1}{2\sigma} + (h_{ij} - h_{ii}) - (p_{ii} - c_i) q_{ii}, \tag{12}$$

where h_{ij} and h_{ii} are decreasing in p_{ij} and p_{ii}, respectively. Thus in this case consumer surplus can be expressed as

$$\begin{aligned} CS &= \frac{1}{2}h_{ii} + \frac{1}{2}h_{ij} - f_i - \frac{1 + 2\sigma(h_{ij} - h_{ii})}{2\sigma} + (p_{ii} - c_i) q_{ii} - \frac{1}{8\sigma} \qquad (13) \\ &= h_{ii} + (p_{ii} - c_i) q_{ii} + \frac{1}{2}(h_{ii} - h_{ij}) - \frac{5}{8\sigma} - f_i \end{aligned}$$

[1] In the following we assume that α_i is always below this limit, so that no connection breakdown occurs.

This expression shows that consumer surplus is driven by the competitiveness of the market. In particular, CS decreases in p_{ii} (and achieves its maximum even below the efficient price p_{ii}^{PD}), but increases in off-net prices p_{ij}. The latter happens because competition between networks, exploiting tariff-mediated network externalities, drives fixed fees so low that consumers are over-compensated for the direct surplus loss due to higher off-net call prices. Let us summarize:

Proposition 1 *In symmetric network competition with two-part tariffs, consumer surplus increases with higher off-net prices.*

Thus our first conclusion is that on/off-net price discrimination increases competitive intensity and benefits consumers. Curiously, this comes at the price of distorting calling patterns away from efficiency. The direct implication of this result is that there is an unresolvable conflict between achieving efficiency (through lower off-net prices) and maintaining consumer surplus.

A second result concerns the effects of asymmetries between networks and follows directly from (10):

Proposition 2 *In the presence of call externalities ($\gamma > 0$), and $a_1 \leq a_2$, the small network sets lower off-net prices and has more outgoing call minutes, $p_{21} < p_{12}$ and $q_{21} > q_{12}$. With reciprocal termination fees $a_1 = a_2 \equiv a$, this creates an access deficit $(a - c_t)(q_{21} - q_{12})$ favouring the large network.*

As a result, small networks tend to make significant net termination payments to their larger rivals, which may impair their ability to expand their consumer base. Naturally, small networks have been lobbying regulators in order to convince them that mobile-to-mobile termination fees should either be lower at large networks or very low for everybody, while large networks insist that there is no competition problem to be solved. Alternatively, it has been proposed that large networks should not be able to set high on/off-net differentials, in order to reduce the imbalance in off-net traffic. We will consider these different measures below.

3.2 Predation

Hoernig (2007) also considers the case where the large network tries to keep the small network's profits below a limit $\bar{\pi}_2$, i.e. it solves the problem $\max_{p_{11},p_{12},F_1} \pi_1$ s.t. $\pi_2 \leq \bar{\pi}_2$. The purpose of this exercise is merely to determine the pricing during an attempt at predation, and not to check whether predation as such is rational or not. We find that with two-part tariffs the on-net price does not change, $p_{11}^{PR} = p_{11}^{PD}$, but that the off-net price changes to

$$p_{12}^{PR} = \frac{c_{f1} + \mu (a_2 - c_{t2})}{1 - \gamma \alpha_1 / \alpha_2}, \tag{14}$$

where $\mu > 0$ is the shadow value of reducing the small firm's profits. This price is distorted upwards as compared to the Nash equilibrium price if termination fees are set above cost. It has the sole purpose of reducing the number of off-net calls and thus reducing the small network's termination revenue.

Yet, with two-part tariffs the main instrument of predation for the large network is the fixed fee: It will tempt customers of the other network by offering a tariff with low fixed fees. Thus contrary to competition with linear tariffs, where predation can only be performed through a low on-net price and a high off-net price, predation with two-part tariffs cannot be stopped by regulating the on/off-net differential. At best, it can be made more expensive for the large network: Since if it will not be able to use off-net prices to lower the small network's termination revenue, it will have to offer even lower fixed fees to have the same effect on the small network's total profits.

Thus regulating destination-based price discrimination can reduce the incentives for predation but not eliminate them. Therefore, in the following we will abstract from the possibility of predation, and only consider "competitive" equilibria.

4 Some Proposed Remedies

In this section we will consider some remedies that have been proposed by various regulators and industry participants in order to deal with the inefficiency and alleged competition problems stemming from tariff-mediated network externalities. We will consider the effects on consumer surplus, networks' profits and total welfare, and show which trade-offs must be made.

The first two remedies involve a direct intervention on retail pricing. Thus they cannot be imposed by sectoral regulators in Europe under the existing regulatory framework for telecommunications. Still, similar interventions on retail pricing were proposed in Portugal in 2006 in the context of the putative merger between two of Portugal's three mobile phone networks. These were accepted by the Portuguese competition authority as merger remedies, and thus would not have had to be imposed under the auspices of the telecoms regulatory framework.[2] The aim of these remedies would have

[2] The merger proposal was later blocked by the General Assembly of Portugal Telecom,

been to protect a putative new entrant who would have taken over spectrum and infrastructure from the merging operators.

The next two remedies refer to wholesale pricing at the termination level, and would thus be applicable under the existing framework for telecommunications regulation in Europe. The first remedy is lowering termination fees for all operators. This decreases on/off-net differentials for the simple reason that it lowers the perceived cost of off-net calls. This remedy would also be aimed at combating the inefficiency related to high off-net prices. We then consider lower termination fees only for large networks, as has been proposed to help small networks.

4.1 Restrictions on Retail Prices

4.1.1 Reducing On/off-Net Differentials

Tariff-mediated network externalities could in principle be reduced or totally eliminated by direct intervention on retail prices. In this and the following section we study two different interventions of this type. In this section we consider a limit directly on the on/off-net differential, while in the next section we study a regulated markup over cost for off-net calls. The difference between the two measures is that the former establishes a link between on- and off-net prices, while the latter only affects the off-net price.

Pricing structure: First assume that a limit $\Delta \geq 0$ is imposed on the on/off-net differential, with the resulting restriction on operator i's retail pricing being $|p_{ij} - p_{ii}| \leq \Delta$. Uniform pricing corresponds to $\Delta = 0$. In the following, we consider Δ low enough so that the restriction is binding: $p_{ij} = p_{ii} + \Delta$, which will be the case if $\Delta < \Delta^{PD} = \frac{c_{fi}}{1-\gamma\alpha_i/\alpha_j} - \frac{c}{1+\gamma}$.

The first result describes equilibrium call prices. The profit-maximizing fixed fees can be found as in section 3 by maximizing profits over market share, and are again given by (11).

Proposition 3 *If network i is subject to a restriction $p_{ij} = p_{ii} + \Delta$, then its equilibrium on-net price is given (implicitly) by*

$$p_{ii} = \frac{c_i + \frac{\alpha_j q'_{ij}}{\alpha_i q'_{ii}} \left(c_{fi} - \left(1 - \frac{\alpha_i}{\alpha_j}\gamma \right) \Delta \right)}{(1+\gamma) + \frac{\alpha_j q'_{ij}}{\alpha_i q'_{ii}} \left(1 - \frac{\alpha_i}{\alpha_j}\gamma \right)} > \frac{c_i}{1+\gamma}, \tag{15}$$

the merger target, so that (unfortunately for researchers in mobile phone markets) this natural experiment did not take place.

Equally, $p_{ij} = p_{ii} + \Delta < \frac{c_{fi}}{1-\gamma\alpha_i/\alpha_j}$*, and* p_{ii} *is strictly decreasing in* Δ *if demand is not too concave. Furthermore, with a uniform tariff the price per call minute is*

$$p_i = c + \alpha_j \left(a_j - c_{it}\right). \tag{16}$$

Proof. As in the derivation of the unrestricted pricing pattern with two-part tariffs, insert (9) into network i's profits while keeping market shares α_i and α_j constant. Profit maximization is then achieved by solving

$$\max_{p_{ii}} \alpha_i \left[\left(p_{ii} - c\right) q_{ii} + v\left(p_{ii}\right) + \gamma u\left(q_{ii}\right)\right]$$
$$+\alpha_j \left[\left(p_{ii} + \Delta - c_{fi}\right) q_{ij} + v\left(p_{ii} + \Delta\right) - \frac{\alpha_i}{\alpha_j}\gamma u\left(q_{ij}\right)\right],$$

where $q_{ij} = q\left(p_{ii} + \Delta\right)$. The resulting first-order condition can be rewritten as (15). The condition $\Delta < \Delta^{PD}$ is equivalent to $p_{ii} > \frac{c_i}{1+\gamma}$ and $p_{ij} < \frac{c_{fi}}{1-\gamma\alpha_i/\alpha_j}$. It can also be shown that the condition $dp_{ii}/d\Delta > 0$ is equivalent to q''_{ij} being larger than some negative number. If uniform pricing or $\Delta = 0$ is imposed, then $q'_{ij} = q'_{ii}$ and we obtain

$$p_{ii} = \alpha_i c + \alpha_j c_{fi},$$

which can be rewritten in its well-known form as (16). ∎

Thus imposing a limit on the on/off-net differential lowers the off-net price and increases the on-net price. While this is not surprising as such, a notable consequence is that pricing no longer reflects the call externality even for on-net calls as one approaches uniform tariffs. The intuition for this result is as follows: Given a uniform price p_i of network i, the number of calls $q_i = q\left(p_i\right)$ received from other customers of network i will not depend on which network a given consumer joins. As a result, in network i's profits the call externality on own customers $\gamma u\left(q_i\right)$ cancels out exactly with the externality $\frac{\alpha_i}{\alpha_j}\gamma u\left(q_i\right)$ on the rivals' customers.

The on-net price can be rewritten as

$$p_{ii} = w_{on} p_{ii}^{PD} + w_{off} p_{ij}^{PD} - w_{off}\Delta, \tag{17}$$

where the "weights" w_{on} and w_{off} still depend on Δ, with $\lim_{\Delta\to 0} w_{on} = (1+\gamma)\alpha_i$ and $\lim_{\Delta\to 0} w_{off} = \alpha_j - \alpha_i\gamma$. It should also be noted that if either demand is linear or exponential ($q\left(p\right) = Ae^{-Bp}$, $A, B > 0$) then (15) yields an explicit solution for the on-net price.

Thus imposing a uniform price, or even just limiting the on/off-net differential, introduces a new inefficiency: On-net calls are priced above the efficient level. In terms of total welfare, this inefficiency must be weighed against the efficiency gains resulting from a lower off-net price. It is therefore not obvious whether uniform pricing or price discrimination leads to higher welfare. In the following we show by way of an example that depending on the shape of demand and other parameter values "anything goes".

Consider symmetric networks and linear demand, with $u(q) = Aq - \frac{1}{2}Bq^2$ and $q(p) = A - Bp$. If the same limit Δ is imposed on both networks, on-net prices will be equal to $p_{ii} = c + (m - (1-\gamma)\Delta)/2$, where $m = a - c_t$. It is straightforward to verify that total welfare W as given in (8) has an interior maximum at the candidate

$$\Delta^* = \gamma \frac{(1+\gamma)\left[2A(B-1) - (2c+m)B^2\right] + 2c}{B^2(1+\gamma)(1+\gamma^2)}.$$

If there is no call externality ($\gamma = 0$) then clearly there is no trade-off and uniform pricing is optimal. When $\Delta^* \leq 0$ then uniform pricing is optimal, while for $\Delta^* \geq \Delta^{PD}$ unrestricted price discrimination is optimal. With linear demand, the outcome depends on whether B is larger or smaller than 1. If $B > 1$, then uniform pricing is optimal if

$$A < A_1 = \frac{1}{2}\frac{B^2(1+\gamma)(2c+m) - 2c}{(1+\gamma)(B-1)},$$

while not imposing restrictions is optimal if

$$A > A_3 = \frac{B^2\left(m(1+\gamma)^2 + 4c\gamma\right) - 2c\gamma(1-\gamma)}{2\gamma(1-\gamma^2)(B-1)}.$$

As concerns the direct comparison between uniform pricing and unrestricted price discrimination, the latter is better if

$$A > A_2 = \frac{B^2\left(m(1+\gamma)(1-\gamma^2+2\gamma) + 2c\gamma(3-\gamma^2)\right) - 4c\gamma(1-\gamma)}{4\gamma(1-\gamma^2)(B-1)}.$$

All three cases may occur since we have $A_1 < A_2 < A_3$ with $B > 1$. As a specific example, consider the parameter values $c = 1$, $B = 2$, $\gamma = 0.1$, and $m = 0.1$. Then $\Delta^{PD} \approx 0.313$, $A_1 \approx 3.29$, $A_2 \approx 6.45$ and $A_3 \approx 9.62$, i.e. for A between 3.29 and 6.45 it is optimal to allow for some price discrimination, but uniform pricing is optimal if A is small. Furthermore, this result even applies with cost-based access: If $m = 0$ we have $A_1 \approx 3.09$, $A_2 \approx 5.13$ and

$A_3 \approx 7.17$. If $B = 1$ then $\Delta^* < 0$, i.e. uniform pricing maximizes welfare. On the other hand, if $B < 1$ then $A_3 < A_2 < A_1$, and uniform pricing is optimal if A is large. It is not even possible to state a generic ordering according to market size A, since this ordering is reversed depending on the slope of demand B.

We summarize the above discussion in the following proposition:

Proposition 4 *In symmetric network competition with two-part tariffs, no generic statements can be made about whether (unrestricted) price discrimination, uniform pricing, or any regulated limited price discrimination, maximizes total welfare. The same applies to the direct comparison between price discrimination and uniform pricing.*

As concerns consumers, the discussion in section 3 immediately implies the following:

Proposition 5 *In symmetric network competition with two-part tariffs, consumer surplus decreases if restrictions are imposed on the on/off-net differential.*

This follows from the increase in p_{ii} and decrease p_{ij}, which both lower consumer surplus.

Limit only on the large network: It has been proposed that small networks could be "protected" from tariff-mediated network externalities by limiting large rivals' on/off-net differentials. We consider this proposal in the following simulation of Figure 1, where only the large network's retail price differential is limited. Since the model cannot be solved analytically, here and in the following we present numerical simulation results for the asymmetric case. Unless indicated otherwise, parameter values are $q(p) = p^{-2}$, $c_i = 1$, $c_{ti} = 0.2$, $f_i = 0$, $\sigma = 1$, $A = 0.2$, $\gamma = 0.1$, and $a_1 = a_2 = 0.3$. The "degree of price differentiation" refers to Δ/Δ^{PD}, i.e. there is uniform pricing at the left border and no restriction at the right border of the following figures.

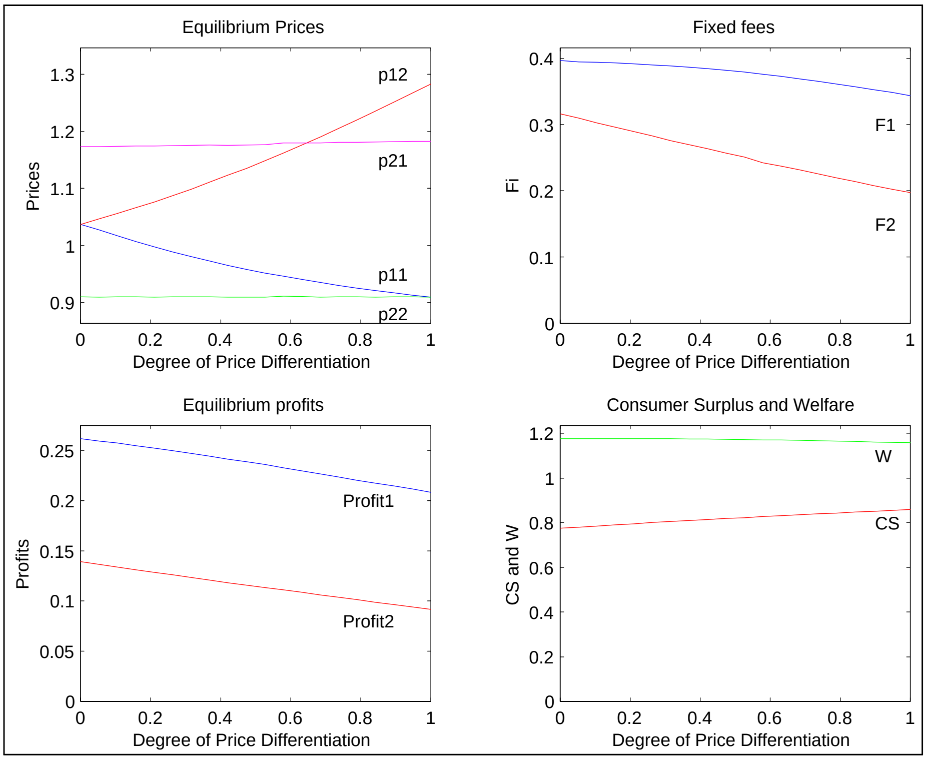

Figure 1: Limiting the on/off-net differential of the large network.

As shown above, the large network's on- and off-net prices converge towards the perceived cost of a call under uniform tariffs. Furthermore, fixed fees, both networks' profits and welfare increase, while consumer surplus decreases as the limit on the large network's on/off-net differential becomes smaller. Thus the trade-offs between welfare, networks' profits and consumer surplus are the same as with the wholesale interventions studied above. Even so, it is worth noting that *both* the small and the large network benefit from the reduction in the large network's on/off-net differential, since competitive intensity is lowered for both networks.

4.1.2 Reducing Off-Net Margins

A related measure which does not imply a rise in on-net prices is that of controlling the margin over perceived off-net cost, i.e. $\delta = p_{ij} - c_{fi}$. Still, its effects are similar to a limit on the on/off-net differential, as the following simulation shows. With $\delta^{PD} = \frac{c_{f1}}{1-\gamma\alpha_1/\alpha_2} - c_{f1}$ as the unrestricted off-net margin, the following Figure 2 is indexed by the relative margin δ/δ^{PD}.

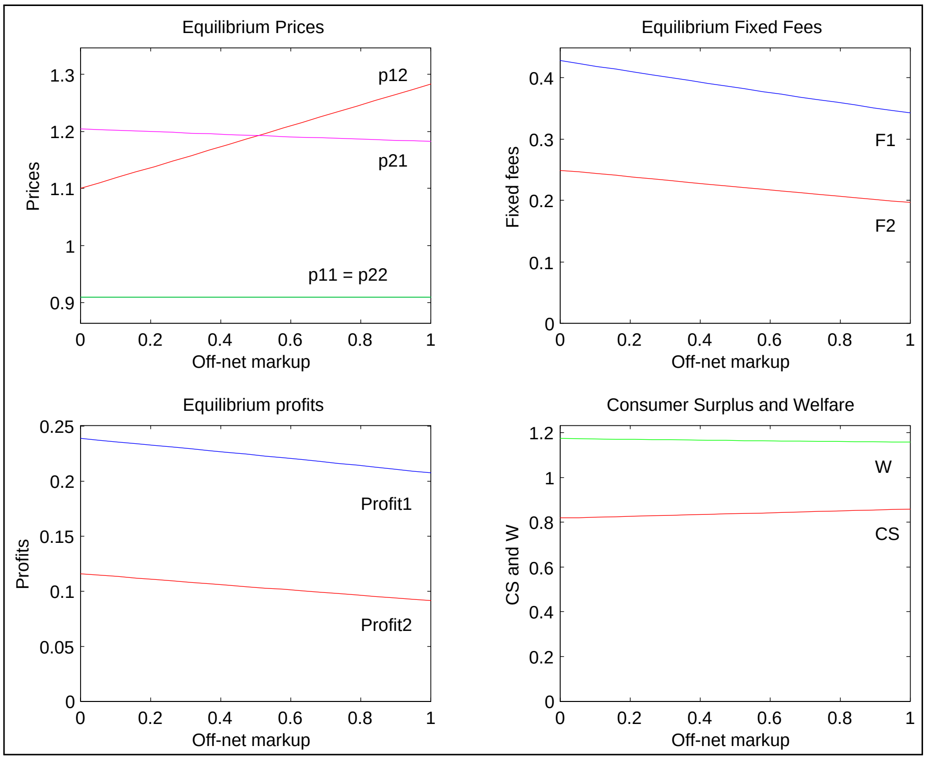

Figure 2: Reducing the off-net margin of the large network.

On-net prices do not change, and the large network's off-net price follows the limit that has been imposed. The small network's off-net price rises due to an increase in market share. As concerns profits and welfare, the picture is familiar: Profits and welfare increase while consumer surplus decreases, so that there does not seem to be any significant difference with a direct limit on the on/off-net differential in this respect.

4.2 Restrictions on Wholesale Prices

4.2.1 Lowering Termination Fees

First consider symmetric networks. LRT and Gans and King (2001) analyzed this case and proved that networks' profits increase with lower termination fees.

This leads to the paradoxical result that if networks were to jointly set a reciprocal termination fee, they would choose it at a level below cost. The latter is the welfare-maximizing value in their setting since there are no call externalities. Since this result is strongly at variance with mobile operators' choices of high mobile-to-mobile termination fees, and therefore regulators' preoccupations, alternative explications for the choice of high termination fees have been sought. Three relevant ones are that either networks set termination fees unilaterally, the existence of calling clubs (Gabrielsen and Vagstad 2008), or that networks are unable to set different prices for the termination of mobile-to-mobile and fixed-to-mobile calls (Armstrong and Wright 2007). In the first case double marginalization occurs, with calling clubs high termination fees reduce competitive intensity, while in the last case termination fees are high because of monopoly rents associated with fixed-to-mobile termination (which will then be competed away through subscriptions, though). In the following we abstract from the question of fixed-to-mobile (F2M) termination, essentially assuming that F2M rates remain unchanged. These would translate into the level of per-customer fixed cost f_i, but would not influence the model otherwise.

Berger (2005) has reconsidered the symmetric case in the presence of call externalities. Qualitatively, the results are similar to the case without call externalities: networks' profits increase with a lower termination fee, while the welfare maximum now occurs at a level below cost. The latter happens because the off-net price $p_{ij} = \frac{c+(a-c_t)/2}{1-\gamma}$ remains distorted upwards through strategic pricing due to the call externality. On the other hand, fixed fees increase, and consumer surplus decreases, with a lower termination fee. We can summarize these known results as:

Proposition 6 *In symmetric network competition with two-part tariffs, reducing termination fees towards cost leads to higher welfare and network profits, and lower consumer surplus.*

A similar but related question is whether qualitatively different results arise if firms are asymmetric. The following Figure 3 presents the results from a simulation with the above-mentioned parameter values.

It is evident that the smaller network charges a lower off-net price and fixed fee and has smaller profits. Apart from this, the effects on profits, welfare and consumers are the same as with symmetric networks. In particular, when mobile-to-mobile termination fees are reduced both networks' profits increase.

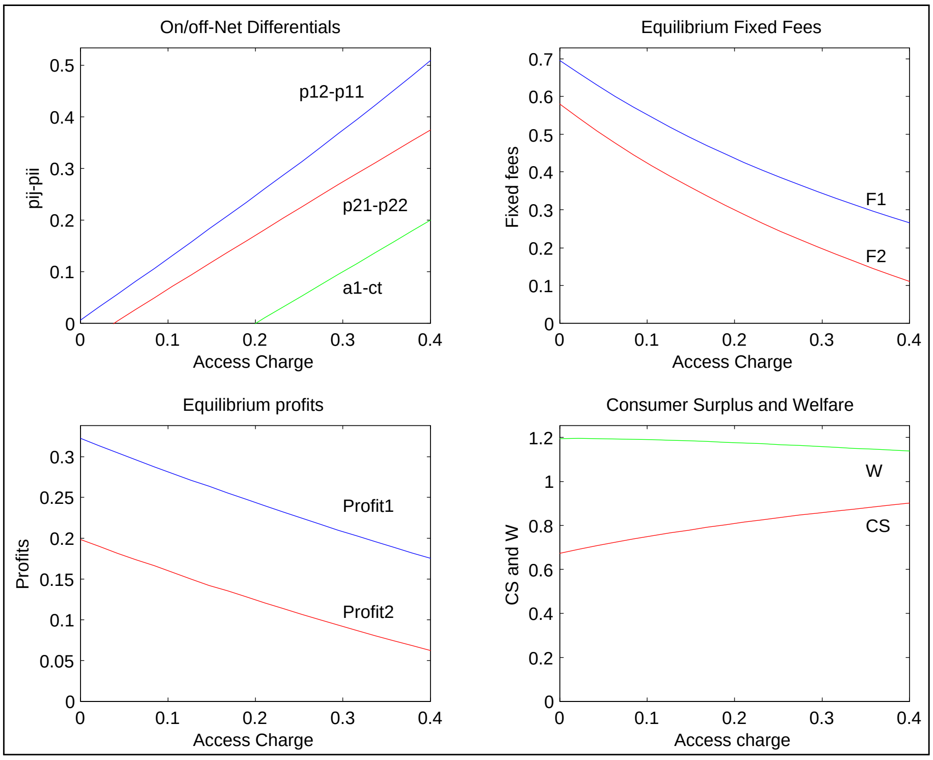

Figure 3: Equal termination charges for both networks

4.2.2 Asymmetric Termination Fees

A related measure whose aim is to compensate disadvantages of small networks is that of allowing for an asymmetry in termination fees, i.e. the small network can charge more for incoming calls than its larger competitor.

Peitz (2005) considers an asymmetry in termination, where the large network's termination fee is fixed at cost and the small network's is raised slightly above cost. Since there are no call externalities in his model, this implies that his point of departure is uniform pricing at the efficient level, and that the large network will subsequently charge a higher off-net price due to the asymmetry in termination fees. As we have seen above, this implies that welfare decreases but consumer surplus increases (Peitz also shows that the small network's profits increase). In this section we will consider the case that is more relevant in practice where present termination fees are above cost and termination fees are adjusted downwards from this level.

As in the previous section, we neglect here the role of fixed-to-mobile interconnection. Nevertheless, a short discussion of the topic seems warranted. A higher F2M termination fee for the small network amounts in our framework to a reduction in f_i relative to the large network, which implies that its fixed fee will decrease by the same amount (This is the "waterbed effect"). Thus asymmetry in fixed-to-mobile interconnection means that the small network can compete through lower fixed fees. A complete welfare analysis of F2M termination must take into account the surplus of customers on the fixed network. Since the additional termination revenue is transferred to mobile customers, but fixed customers also support a deadweight welfare loss due to higher call prices, an increase in F2M termination fees tends to reduce total welfare, unless there are strong positive effects of subsidizing mobile customers such as network effects when mobile penetration is still low. If an asymmetry is introduced on both F2M and M2M termination fees then these effects and the one described below are superimposed and are difficult to disentangle.

As above, analytical results are not available with asymmetric networks, therefore in Figure 4 we present a simulation using the same parameter values. In addition, we have assumed that the small network charges termination above cost ($a_2 = 0.3$), and loop over the large network's termination fee $a_1 \leq 0.3$.

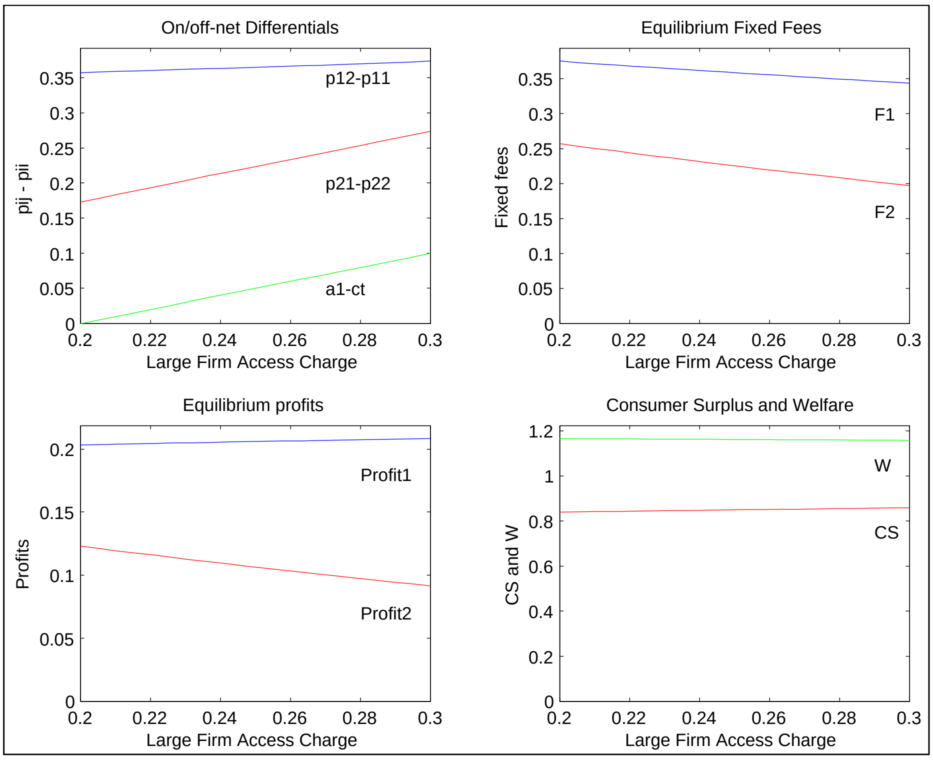

Figure 4: Asymmetric M2M termination charges.

When the large network's termination fee is lowered, both networks' off-net prices decrease. The small network's price decreases due to the direct effect of lower perceived cost, while the large network's price decreases somewhat due to a loss of market share. Profits of the small network increase, while those of the large network decrease, due to a larger market share of the small network and the reduction in the access deficit. On the other hand, both fixed fees go up and consumer surplus decreases, while welfare increases. Indeed, for these parameter values the latter achieves a maximum slightly above cost-based access for the large network.

These results indicate that asymmetric mobile-to-mobile termination fees benefit the small network, at the expense of the large network and consumers. Yet, comparing these simulation results with the ones for the same reduction in termination fees for both networks, one finds that welfare and the small firm's profits are slightly higher in the latter case, while consumer surplus is lower.

That is, a reduction of M2M termination fees only on the large network yields about the same profits for the for the small network as the same reduction applied to all networks, while consumers are better off. While the fundamental trade-off between reducing tariff-mediated network externalities and preserving consumer surplus continues to exist, asymmetric termination fees raise profits of the small network by transferring revenue from the large network, and less by lowering consumer surplus.

5 Conclusions

We have considered a model of competition between two interconnected telecommunications networks and how price discrimination between on- and off-net calls affects welfare, profits and consumer surplus. While price discrimination leads to inefficiency by reducing off-net call minutes, it tends to increase competitive intensity and thus consumer surplus.

Our results show that even in this stylized model it is hard to come to unambiguous conclusions about the effects of regulatory measures. First of all, whether some measure should be adopted or not depends on the social planner's objective, for instance, whether he maximizes total welfare or follows a consumer surplus standard. There tends to be a conflict between increasing total welfare and increasing consumer surplus, because interventions that reduce the misallocation resulting from on/off-net differentials tend to reduce the intensity of competition between networks.

A similar effect occurs when the social planner intervenes to shore up the profits of a small networks, with the aim of avoiding market exit in the long run. Again competitive intensity in the market is reduced, and consumer surplus decreases. Thus the social planner must trade off lower consumer surplus in the short run for a reduced probability of exit of the small network in the future.

A second main conclusion is that the welfare-maximizing choice between price discrimination and uniform pricing (or anything between) depends on the exact characteristics of demand, which will normally not be known to a sufficient degree by industry regulators. Any intervention then carries the risk that it may lower welfare rather than raise it.

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