

Why is on-net traffic cheaper than off-net traffic?*

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Abstract

Received literature have shown that if competing Telecom networks are restricted to linear pricing and are unable to discriminate between on- and off-net calls, high access charges can be a device for facilitating collusion. Under more general pricing schemes (allowing non-linear pricing and price discrimination between on-net and off-net traffic) high access charges are more difficult to sustain, because they reduce consumers' willingness to pay fixed fees. We show that an unbalanced calling pattern is sometimes sufficient to restore high access charges as an equilibrium outcome.

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1 Introduction

Telecom network charges typically involve discrimination against off-net traffic, and mobile telephony is a case in point. What matters for how much a person pays for

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a call to somebody else is often not the physical distance between the two mobile phones involved, but whether they subscribe to the same mobile phone operator or not. Arguably, there might be cost components associated with traffic between networks only, and then the observed pricing pattern may reflect the underlying costs. This answer is not satisfactory, however: a closer inspection reveals that by far the most important cost determinant of a marginal call to another network is the access fee (termination charge) charged by the receiving network, increasing the "economic" distance between subscribers of different networks. From an industry perspective access fees are not real costs, since they pop up in the receiving network's revenues, and this give rise to another question: Why are the access charges so high?¹

Armstrong (1998) and Laffont, Rey and Tirole (1998a) have suggested that access charges are high because firms want high prices, and high access charge makes them charge high prices.² In a model with linear and uniform pricing, high access charges implies high perceived marginal costs and high prices, but the high costs are then compensated for by correspondingly high access revenues. Consequently, high access charges can be an instrument for collusive pricing. This is not a compelling explanation in markets like the market for mobile telephony, however. Laffont, Rey and Tirole (1998b) demonstrate that if the operators can discriminate between on-net and off-net traffic and have access to two-part tariffs, high access fees can no longer be used to facilitate high prices.³ On the contrary, high access charges tend to reduce equilibrium profits, as the access charge makes the firms distort consumer prices with an implied welfare loss.⁴ With two-part tariffs this means that the

¹The same argument applies to ordinary telephony: before the services were automatized, the costs of "producing" a call were an increasing function of the distance between the points of origination and termination of the call, because long-distance calls had to pass more manual switchboards. Today, however, practically all costs of producing telephone calls are fixed costs. The downward trend in prices of international phone traffic is a reflection of this cost structure.

²For an excellent survey of the theory of access pricing and interconnection, see Armstrong (2001).

³See also Laffont and Tirole (2000, Section 5.5).

⁴In fact, recently Gans and King (2001) have shown that in this context access prices should be subsidized, i.e., should be lower than marginal costs of terminating a call.

consumers are willing to pay a smaller fixed fee.⁵ In many Telecom markets, linear and uniform prices are the exception rather than the rule. It thus remains an open question why we do observe high access charges and large price differences between on- and off-net traffic in such markets.

We propose an answer to this puzzle based on the combination of — or interaction between — three different features which we believe characterize the markets in question. The first is the *tariff-mediated network externalities* that arises when firms discriminate against off-net traffic: subscribing to a large network lowers the average price of calls. These are already present in Laffont, Rey and Tirole’s (1988b) analysis and are not sufficient to facilitate collusive pricing on their own. The second is the existence of *exogenous switching costs*: consumers have a relationship with one of the suppliers, and there are certain costs attached to switching supplier. As shown by Klemperer (1987, 1995), such switching costs facilitate collusive pricing, but with two-part tariffs and non-uniform pricing, there are no reasons to deviate from efficient pricing: marginal prices (access charges inclusive) should equal marginal costs, and the market power that arises should be used to increase the fixed fee of the two-part tariff. Consequently, the existence of switching costs alone is no reason to set high access charges.⁶ Third, despite the fact that mobile phone owners can reach millions of other persons (increasing to billions if we also count international calls), they place their calls to a limited number of people, among which friends, family and workmates comprises the bulk of the recipients. The notion of a *calling club* captures the phenomenon that individuals do not place their calls randomly across networks, but have a bias towards calling other members of their calling club (their ‘friends’). Since these are persons that are called regularly, it is reasonable to assume that their network location is known by all club members.

The combination of calling clubs and tariff-mediated network externalities is potentially forceful: with higher off-net than on-net prices, members of the same

⁵In an attempt to restore the collusion effect from high access charges Dessein (2000) introduces heterogeneity in volume and subscription demand. However, neither of these features are sufficient to restore the result of high access charges in equilibrium. Moreover, Dessein (2000) does not allow networks to charge different prices for on-net and off-net calls.

⁶See also Gabrielsen and Vagstad (2002).

calling club would benefit from joining the same network, *ceteris paribus*. Once they have coordinated on the same network, each member of the calling club has a preference for remaining with that network, giving rise to similar effects as if the products were horizontally differentiated (e.g. in the Hotelling sense). Switching to another network will make it more expensive to reach one's friends in the old network and by that make it more expensive to make an average call, even if both networks charge identical prices and have the same size (i.e. the same number of subscribers).⁷ Consequently, also this type of consumer lock-in will reduce competition, albeit at a certain cost: as long as high access charges do not reflect real costs, price discrimination based on call termination is inefficient and will reduce surplus compared to a situation in which firms set all marginal prices at their marginal costs.

We present a simple model where two networks that are symmetric in costs and customer bases first jointly set a common access charge and then simultaneously and independently offer consumers two-part tariffs, possibly discriminating on the basis of call termination. The population of consumers 'belong' to either network from an unmodelled initial period, and they incur exogenous switching costs if they want to switch supplier.⁸ With access charges above the marginal termination cost, firms will price discriminate against off-net calls, implying that members of a calling club should choose to subscribe to the same network. On the other hand, if calling clubs are located in the same network, price discrimination will tend to increase individual switching costs which may enable firms to charge higher fixed fees. The basic question we explore is whether the latter effect may be strong enough to dominate the inefficiency effect so as to make the firms prefer high access charges and price discrimination based on call termination.

A first result is that it turns out to be far from easy to describe situations

⁷Apart from the literature on networks discussed above, our model also relates to the literature on network compatibility (see for instance Katz and Shapiro (1985)). However, this literature is more concerned with consumer expectations and the existence of multiple equilibria which is not an issue here.

⁸Although our analysis is couched in a switching cost framework, we believe that our results are robust to alternative modes of competition. The switching costs in our model can be reinterpreted as the transport cost in a Hotelling type differentiation model.

in which the above-mentioned benefits from reduced competition exceed the costs. For instance, without exogenous switching costs we have not been able to find such situations, despite the fact that the two effects of inflating the access charge (reduced competition and reduced efficiency) are present also in the absence of exogenous switching costs.

Moreover, if the exogenous switching costs are 'high enough,' there is no scope for setting a markup on access either: with high enough switching costs, firms can fully extract consumers surplus without worrying that the rival network will try to poach their customers. In this context, a mark-up on access yield higher off-net prices which creates inefficiencies that can only contribute to a reduction of firms' profit. However, for lower levels of exogenous switching costs we have found situations in which high access charges yield a pure-strategy continuation (pricing) equilibrium involving discrimination against off-net traffic, with higher profit for the firms than the reference case in which the access charge is set at marginal cost.

What remains of the paper is organized as follows. The next section contains the model and our main results. In Section 3 we discuss our modelling choices and the robustness of our results, and Section 4 concludes. Proofs are relegated to the appendix.

2 The model

Consider a market with two firms or networks denoted $i = 1, 2$. Each network has a unit mass of consumers from an unmodelled initial period. Each consumer places one call.⁹ Utility (gross of payments) of a quantity y of a call equals

$$u(y) = \begin{cases} y - \frac{1}{2}y^2 & \text{if } 0 \leq y \leq 1 \\ \frac{1}{2} & \text{if } y > 1 \end{cases} \quad (1)$$

This utility function yields rather simple linear demand, and the utility does not depend on who is the recipient of the call. This latter feature of the specified utility

⁹Equivalently, each consumer places a unit mass of calls, distributed according to the description below.

function helps us get rid of a lot of problems associated with price discrimination based on consumer heterogeneity and customer base composition.¹⁰

If the price of the call is p per unit, (1) yields the following demand function:

$$y(p) = \begin{cases} 1 - p & \text{if } 0 \leq p \leq 1 \\ 0 & \text{if } p > 1 \end{cases} \quad (2)$$

and the maximum utility from the call is given by the following indirect utility function:

$$v(p) = \begin{cases} \frac{1}{2}(1 - p)^2 & \text{if } 0 \leq p \leq 1 \\ 0 & \text{if } p > 1 \end{cases} \quad (3)$$

We assume that the firms have zero marginal costs and that they can discriminate between on-net and off-net calls. The firms jointly decide the marginal access charge a and then independently and simultaneously offer consumers two-part tariffs. A tariff $\{k, p, q\}$ consists of a fixed fee k , a marginal price p for calls terminated in the originating network (internal/on-net price) and a price q for calls terminated in the rival's network (export/off-net price).

Next, we assume that with probability α the call is to a member of one's calling club, and with $(1 - \alpha)$ the call is to an arbitrary person. Moreover, the following assumptions are made about the calling clubs:

- A1. Members of the same calling club initially belong to the same network.
- A2. There are no overlap between calling clubs.
- A3. Members of the same calling club have identical exogenous switching costs.

Assumption A1 can have several interpretations. The most obvious economic explanation is perhaps that if it has been common to discriminate against off-net traffic, friends have eventually coordinated on the same network in order to save on calling expenditures¹¹, but it may also simply be because friends are more likely

¹⁰See Gabrielsen and Vagstad (2001) for an analysis of price discrimination based on customer base composition.

¹¹Having $p < q$ will generate tariff-mediated network externalities and consumers have incentives to sort when choosing their network: friends will coordinate on the same network in local calling clubs. Complete sorting could happen when $p < q$ e.g. if friends enter sequentially and in pairs and that the firms charge identical prices.

to have similar preferences and therefore tend to subscribe to similar services.¹² Assumptions A2 and A3 simplifies the technical analysis. To simplify discussion, in what follows we will assume that a calling club consists of only two persons, but this is not restrictive as long as each calling club has a negligible mass of consumers.

For a given tariff $\{k, p, q\}$ the equilibrium utility of a representative consumer of network i is given by

$$u_i = \underbrace{\alpha v(p)}_{\text{friends}} + \underbrace{(1 - \alpha) \left(\frac{1}{2} v(p) + \frac{1}{2} v(q) \right)}_{\text{others}} - \underbrace{k}_{\text{fixed fee}} \quad (4)$$

The corresponding profit of firm i is

$$\pi_i = \alpha y(p)p + (1 - \alpha) \left(\frac{1}{2} y(p)p + \frac{1}{2} y(q)(q - a) \right) + k + R(a, q') \quad (5)$$

where $R(a, q') = \frac{1-\alpha}{2} ay(q')$ is the access revenues from the other network's consumers, when the other network has set export price q' . Note that $R(0, q') = 0$. Moreover, if $a = \infty$, a rational firm would not induce any demand for off-net calls, hence $y(q') = 0$ and therefore $R(\infty, q') = 0$.

Suppose both firms charge $q = a > p = 0$ and some fixed fee $k \geq 0$. This pricing would induce an inefficient quantity of off-net calls and loss in consumers' surplus. Clearly, if consumers are perfectly flexible and the firms' products are perfect substitutes no such equilibrium is sustainable. The reason is that any of the firms could poach all of the rival's customers by lowering its export price to zero. The undercutting firm would double its customers base and could even charge a higher fixed fee from all consumers due to increased consumer surplus. Since all consumers switch there is no need to worry about a deficit on access charges. Therefore, in order to generate the equilibrium we are looking for, either the firms' products must be differentiated in some sense, or some consumer inflexibility must be assumed. This is the reason why we have incorporated exogenous switching costs in our model. To be more precise, we assume that there are exogenous costs s attached to switching supplier. We further assume that s is uniformly distributed

¹²Alternatively, friends may have acquires mobile phones at the same times by responding to campaign offers by one of the networks.

on $[0, \bar{s}]$ with density $g(s) = \frac{1}{\bar{s}}$ and CDF $G(s) = \frac{s}{\bar{s}}$ over the entire support.¹³ Hence, $G(s)$ is the proportion of a firm's consumers whose cost of switching to the other firm's product is less than or equal to s .¹⁴ We will restrict attention to cases in which $\bar{s} \leq \frac{1}{2}$, i.e. the switching costs are not too high, since if not, the two firms will behave like perfect monopolists even without any markup on access (see Gabrielsen and Vagstad (2002)).

As indicated, our primary interest is in whether it pays for the firms to set a markup on access, i.e., $a > 0$. It turns out to be quite difficult to describe what happens with prices for some values of the access charge. Therefore, in the formal analysis we restrict attention to two polar cases: either $a = 0$ or $a = \infty$, and discuss more loosely the pricing equilibria for the intermediate values. For each of the polar cases we look for a pure-strategy continuation equilibrium in the subsequent pricing game.

When $a = 0$ Gabrielsen and Vagstad (2002) have shown the following result (which is a relatively straightforward extension to Klemperer (1987)):

Proposition 1 *When $a = 0$, and $\bar{s} \leq \frac{1}{2}$ there exist a unique pure strategy equilibrium involving*

$$p = q = 0 \tag{6}$$

$$\pi = k = \frac{1}{g(0)} = \bar{s} \tag{7}$$

When $a = 0$ there is no reasons for the firms to set inefficient marginal prices, hence $p = q = 0$ for both firms, and the socially optimal surplus is always achieved. Competition only affects the fixed fees. As usual in switching costs models, whether or not an equilibrium in pure strategies exists depends on the distribution and size

¹³Other distributions yield qualitatively similar results, as long as the distribution is smooth, atomless and has a positive density at $s = 0$ (cf. Klemperer, 1987).

¹⁴The interpretation of s can either be the traditional switching cost interpretation that the products are ex-ante homogeneous but ex-post differentiated. However, an alternative interpretation of s is that products are both ex-ante and ex-post differentiated. The latter interpretation would imply that s is the consumers' transport cost of purchasing other than his preferred brand in a Hotelling type differentiation model.

of the consumers' switching costs (see Klemperer, 1987). Moreover, when such an equilibrium exists, the equilibrium fi

we look at the effects of "economically disconnecting" the two networks by setting $a = \infty$. This facilitates much simpler characterization of optimal undercutting strategies. In particular, it turns out that we can restrict attention to two simple undercutting strategies. With $a = \infty$, optimal undercutting either involves off-net calls at marginal cost if you suspect cornering the market, or the price of off-net calls will be set prohibitively high if undercutting does not involve cornering the market, in order to avoid running an infinitely large deficit on access.

Consequently, suppose $a = \infty$. If an equilibrium in pure strategies exists, it must entail $p = 0$ and $q \geq 1$. Moreover, network externalities and the existence of local calling clubs ensures that the only candidate for pure-strategy equilibrium is monopoly pricing in the sense of extracting all consumer surplus through the fixed fee. Consequently, equilibrium must entail

$$\begin{aligned}
 k &= \alpha v(0) + (1 - \alpha) \left(\frac{1}{2} v(0) + \frac{1}{2} v(a) \right) \\
 &= \alpha v(0) + (1 - \alpha) \frac{1}{2} v(0) = \left(\alpha + (1 - \alpha) \frac{1}{2} \right) v(0) \\
 &= \frac{1}{2} (\alpha + 1) v(0) = \frac{1}{4} (\alpha + 1)
 \end{aligned} \tag{8}$$

There will be no access revenues, implying that equilibrium profit equals

$$\pi = k = \frac{1}{4} (\alpha + 1) \tag{9}$$

This will constitute an equilibrium if no firm can make a profitable deviation by undercutting its rival.

As discussed above, with $a = \infty$ there are only two reasonable ways to undercut. First, if a firm undercuts in a way that not all the rival's customers would switch, optimal undercutting must entail $q \geq 1$, implying that the demand for off-net calls is zero. The reason is that if $q < 1$ and a customer would make a call to the rival network, the undercutting firm would incur an infinitely large access deficit on this single call. However, if all consumers switch this problem evaporates since there are no one to call in the other network. Therefore, if a firm undercuts to get all the rival

low, the benefits from more customers and increased efficiency may outweigh the access deficit and optimal undercutting most likely will involve both off-net and on-net calls equal to marginal costs.

customers, he should set as low an export price as possible, i.e. $q = 0$.¹⁸

Let us first look at the situation where a firm try to attract only a fraction $x < 1$ of his competitor's customers. As already discussed, when $a = \infty$ he must be careful not to induce demand for off-net calls, consequently $q \geq 1$ and $y(q) = 0$. Assume that a share $x = G(z) \in (0, 1)$ of the consumers switch to the undercutting network, meaning that consumers with switching costs less than or equal to z switch. The share x will depend on the undercutter's p and k in a continuous way.

The undercutting firm solves the following program:

$$\begin{aligned}
& \max_{p,k,x} \left\{ (1+x) \left(\alpha y(p)p + (1-\alpha) \left(\frac{1+x}{2} y(p)p + \frac{1-x}{2} y(q)(q-a) \right) + k \right) \right\} \\
& \text{s.t.} \quad \alpha v(q) + (1-\alpha) \left(\frac{1}{2} v(p) + \frac{1}{2} v(q) \right) - k \geq 0 \\
& \quad \alpha v(p) + (1-\alpha) \left(\frac{1}{2} v(p) + \frac{1}{2} v(q) \right) - k \geq 0 \\
& \quad \alpha v(q) + (1-\alpha) \left(\frac{1+x}{2} v(p) + \frac{1-x}{2} v(q) \right) - k \geq z \\
& \quad \alpha v(p) + (1-\alpha) \left(\frac{1+x}{2} v(p) + \frac{1-x}{2} v(q) \right) - k \geq z \\
& \quad G(z) = x \\
& \quad q \geq 1
\end{aligned} \tag{10}$$

where the first constraint secures that the consumer without switching cost will switch, and the second secures that his friend will switch. Similarly, the third constraint secures that the consumer with switching cost of exactly z will switch, and the fourth that his friend will switch.

Next consider undercutting by setting $q = 0$. This can only be profitable if all consumers switch, i.e. if $x = 1$. (Note that the reverse is also true: if the undercutting firm corners the market, there is no reason to set $q > 0$.) Then the undercutting firm maximizes:

$$\max_{p,k} \{ 2(y(p)p + k) \}$$

¹⁸Here one could argue that if all consumers switch there is no need to specify off-net prices since if all consumers belong to the same network, off-net calls are irrelevant. However, the specification of the off-net tariff is important for the individual (pairs of) consumers' decision of whether to switch or not.

$$\begin{aligned}
\text{s.t. } \quad & \alpha v(q) + (1 - \alpha) \left(\frac{1}{2}v(p) + \frac{1}{2}v(q) \right) - k \geq 0 \\
& \alpha v(p) + (1 - \alpha) \left(\frac{1}{2}v(p) + \frac{1}{2}v(q) \right) - k \geq 0 \\
& \alpha v(q) + (1 - \alpha) v(p) - k \geq \bar{s} \\
& \alpha v(p) + (1 - \alpha) v(p) - k \geq \bar{s}
\end{aligned} \tag{P2}$$

where the two first constraints ensure that the first consumer and his friend switch, and last two is to make the last consumer (i.e., the consumer with $s = \bar{s}$) and his friend switch.

Suppose first that $\alpha = 0$, meaning that the call is equally likely to be terminated internally as externally. If so we have:

Proposition 2 *Assume that $\alpha = 0$ and $\bar{s} \geq \frac{1}{4}$. Then no pure-strategy equilibrium with $a = \infty$ can be sustained.*

Proof: See the appendix.

$\alpha = 0$ means that consumers have no intrinsic preferences for their calling club's initial network, so if prices are uniform they are equally inclined to terminate the same amount of calls in each net. With high access fees there is therefore a substantial loss in consumers' surplus as half of the calls are not taken due to prohibitively high off-net prices. This create a strong incentive for each firm to undercut each others prices. Attracting consumers to the same network and charging efficient marginal on-net prices will increase consumers' surplus. On the other hand, switching consumers will have to be compensated for bearing their switching costs. In this case the increase in consumers' surplus always dominates the cost of compensating consumers for their switching costs, hence firms will always undercut each other. Even if no pure-strategy equilibrium exist, there always exists an equilibrium in mixed strategies. This equilibrium is difficult to compute.¹⁹ However, it is clear that the equilibrium profit in any mixed-strategy equilibrium involving $a = \infty$ must be less than $\frac{1}{4}$ in this model. Hence, from Proposition 1 we see that for \bar{s} sufficiently high ($\bar{s} > \frac{1}{4}$) the pure-strategy equilibrium involving $a = 0$ dominates any mixed-strategy equilibrium with $a = \infty$.

¹⁹See footnote 16.

As is common in switching cost models, undercutting may be tempting because it increases your market share. Here, undercutting is even more tempting because it not only increases your market share, but it also reduces an inefficiency due to too high off-net prices. Highly inefficient outcomes are very difficult to sustain as pure-strategy equilibrium outcomes, and if they are it would require very high consumer switching costs.²⁰ Here, only if \bar{s} is at its maximum, i.e., $\bar{s} = \frac{1}{2}$, can such an equilibrium be sustained, and then the firms are exactly indifferent between undercutting and not, meaning that it is optimal to induce switching of exactly a share $x = 0$.

The non-existence result above is interesting because it suggests that a pure-strategy equilibrium with high access charges may exist if consumers place more on-net calls than off-net calls. The reason is that the consumers' loss from high access charges would be smaller in this case, hence they would be more reluctant to switch. Hence, for $\alpha > 0$ we can not rule out that a pure-strategy equilibrium with $a = \infty$ may exist. Also, as we can see from (9) above, if such an equilibrium exists, the equilibrium profit would be increasing in α . If we can find existence of a pure-strategy equilibrium with $a = \infty$, an interesting question is whether such an equilibrium yields higher profits than the equilibrium with zero access fee. The following two propositions demonstrate that the answer to both these questions is yes.

Proposition 3 *Suppose $\alpha = \frac{1}{2}$. Then if $\bar{s} \in [\frac{1}{3}, \frac{1}{2}]$ there exists a pure strategy equilibrium with $a = \infty$ involving*

$$p = 0, \quad q \geq 1 \tag{11}$$

$$\pi_i = \frac{3}{8} \tag{12}$$

²⁰This effect from undercutting was first stressed by Gabrielsen and Vagstad (2001). In their model inefficiencies arised due to screening of heterogeneous consumers. As it is well-known second degree price discrimination involves inefficient contracts to low demand types. Undercutting relaxes the incentive compatibility constraint for the high types, hence inefficiencies in low demand contracts can be reduced. The authors show that this makes undercutting more tempting with a mixture of low and high types than if all consumers were high types only.

Proof: See the appendix.

When exogenous switching costs are sufficiently high there exist a pure strategy equilibrium in which the firms charge infinitely high access charges. In comparison to when access charges are at marginal cost, high access charges create an inefficiency in reducing the amount of off-net calls (in this extreme situation the price of off-net calls is prohibitively high). It should be pointed out that the result in Proposition 2 gives a sufficient condition. We conjecture that the same result could also go through for lower \bar{s} , but this has been difficult to prove. The condition $\bar{s} \geq \frac{1}{3}$ secures that the optimal undercutting strategy is to choose $x = 1$, i.e. undercutting entails inducing all the rival's customers to switch. For $\bar{s} < \frac{1}{3}$ it may in principle be optimal to go after only a fraction of your rival's customers, but it is highly unlikely. The reason is that if it is optimal to go after all customers when switching costs are high, it must also be optimal to do that if switching costs are low. However, in the present model it is difficult to obtain an explicit solution for the optimal undercutting strategy in this case without fixing \bar{s} .

However, our central aim is to prove that it indeed may be profitable to charge high access prices also when two-part tariffs and non-uniform pricing can be used. The following proposition establishes this result:

Proposition 4 *When $\alpha = \frac{1}{2}$ and $\bar{s} \in [\frac{1}{3}, \frac{3}{8})$ there exists a pure strategy equilibrium in which the firms charge infinitely high access charges and earn higher profit than when they charge $a = 0$.*

Proof: Follows directly by comparing Propositions 1 and 3.

The essence of Proposition 4 is that there exists an equilibrium in which firms jointly can decide on highly inefficient access charges, but still earn more than when access charges are at marginal costs. When switching costs are high enough, access charges at marginal cost and efficient and uniform prices are unbeatable. As switching costs get lower, with uniform prices firms would have to lower their fixed fees in order to make it unprofitable for firms to undercut each other. Consumers, of course, benefit from this. High access charges and non-uniform prices for on- and off-net calls have the benefit of creating strong network externalities that may add

to the existing exogenous switching costs consumers may have. Although this type of pricing creates inefficiencies it enable firms to extract the full surplus of their customers. We have shown that the latter effect may dominate the inefficiency effect. It may be better to get a large share of a small pie, than a small share of a large pie.

3 Discussion

We have restricted attention to comparing the extreme situations where a is either zero or infinitely high and have identified situations in which it pays for the firms to set access charges at infinity. Clearly, this does not preclude intermediate values of a from yielding even higher profit. However, if this is the case, this just supports our main claim: the combination of calling clubs and exogenous switching costs may make firms set a positive markup on access, which subsequently yields higher off-net than on-net prices. The problem with the intermediate values of a is that they do not necessarily yield pure-strategy equilibria, it is difficult to verify whether a proposed pure-strategy equilibrium is indeed an equilibrium (due to problems with characterizing optimal poaching strategies), and we do not know whether the profit-maximizing equilibrium is in pure or mixed strategies.

As noted above, unless optimal undercutting entails cornering the market, the optimal undercutting off-net price may be below a , but need not be zero. The reason for this is that cutting the off-net price to zero may be too costly in terms of inducing a too large deficit on access. In spite of this limitation, we have managed to prove our main result, namely that the inefficiencies created by high off-net prices may be more than offset by a greater ability to extract rent from the consumers due to the added lock-in effect created by network externalities and local calling clubs.

The intuition is rather clear: high access charges creates strong network externalities and thereby strong incentives to locate in the same network as friends. Once there, consumers will be loyal to this network in so far as – for equal prices – there are switching costs associated with relocating away from friends. For firms, increased loyalty give room for higher prices and thereby higher profit. This must of course be balanced against the distortions costs of high export prices – a cost that

tends to be born by the firms if consumers are relatively homogeneous and two-part tariffs can be used.

Previously we have experimented with several alternative formulations of our model. Despite the clear intuition above it has been quite difficult — for technical as well as non-technical reasons — to model situations in which the benefits of higher prices exceed the costs of increased distortions. In particular, if nothing keeps customers from switching networks, the tipping properties of the kinds of markets studied here are so strong that equilibria with high access charges cannot profitably be sustained. We have also worked with a model where some consumers have zero switching costs, while others are inflexible in the sense that they would never consider switching. In such a model it is easy to show that with $a = 0$ there exists only a mixed strategy equilibrium. However, this equilibrium always dominates an equilibrium in which firms charge a high price on access and discriminate against off-net calls. The intuition is that when some consumers are perfectly flexible it becomes extremely tempting to undercut to poach these consumers from your rival. In order to prevent this, fixed fees must be low and combined with the inefficiency effect from high off-net prices this can never be profitable.

In the same type of model, with a share of perfectly locked-in consumers, we have also experimented with more inelastic demands. Intuitively, when demand is inelastic the inefficiency loss from high access prices is limited. The problem is that, while reducing inefficiencies, inelastic demand more than proportionally increases the incentives to undercut. The reason is that the temptation to undercut in these type of models is reduced by the fear of an access deficit (since you can never corner the market). As it turns out, with inelastic demand access deficit is less of an issue than with elastic demand. This is easy to understand when considering perfectly inelastic demand. In this case access revenues will equal access expenditures whatever the marginal prices are (as long as a is the same for both firms), hence more inelastic demand will necessitate lower fixed fees and therefore result in lower profit for the firms.

To eliminate these problems, we have chosen to work with a model in which all consumers have exogenous switching costs, but we conjecture that also other forms

of introducing imperfect competition would produce similar results. In particular, given the conceptual similarities between switching costs and Hotelling type differentiation, we suspect that the latter type of model would produce similar results.

We conclude with a comment about the relationship between the model presented here and Laffont et al. (1998b). The fundamental difference between their model and ours is that we assume the existence of local calling clubs where friends may coordinate on the same network. We find this assumption especially compelling when it comes to exploring equilibria where firms discriminate against off-net calls. The existence of coordinated calling clubs tend to bias the calling pattern in favor of on-net calls, a feature not present in Laffont et al (1998b). Whether consumers are 'locked-in' to a network with switching costs or by transportation costs (as in Laffont et al.) this calling bias will increase the individual costs of switching supplier and therefore support higher fixed fees. The simple reason is that when considering to switch, a larger fraction of your calls will have to be off-net calls, or reversely, staying with your original network creates a high consumers' surplus because a large fraction of your calls are internal calls at a low marginal price. As it turns out, this feature may be sufficient to tilt the equilibrium in favor of high access charges and discrimination based on call termination.

4 Concluding remarks

Previous literature have shown that high access charges between competing Telecom networks can be used as a device for facilitating collusion. This result is obtained under linear pricing and when firms are unable to discriminate between on and off-net calls. If firms can offer two-part tariffs and can discriminate between on- and off-net calls, high access charges are no longer profitable; it will only induce inefficient prices and thereby loss of revenues for the networks. An apparent puzzle therefore is why networks typically charge high access charges leading to inefficient prices of off-net calls.

In this paper we have shown that, under different assumptions than in the previous literature, it can indeed be profitable for two independent networks to agree

on high access prices in order to generate higher off-net than on-net marginal prices. The contribution of this paper is to introduce exogenous switching costs in combination with local calling clubs. Higher off-net than on-net prices gives consumers an incentive to locate on the same network as friends. If so, the same non-uniform pricing structure raises the individual switching costs for consumers and enable firms to more fully extract the consumers surplus. We have shown that this profit extraction effect may dominate the efficiency loss stemming from too high off-net prices.

5 Appendix:

Proof of Proposition 2:

Let us first look at the situation where a firm undercuts by setting $q \geq 1$, which is the rational way to undercut iff $x < 1$. If so, we have that $y(q) = 0 = v(q)$. Consequently, program $(\mathcal{P}1)$ can be simplified as follows (when $\alpha = 0$ the second and forth constraints in $(\mathcal{P}1)$ collapse with the first and third):

$$\begin{aligned} \max_{p,k,x} & \left\{ (1+x) \left(\frac{1+x}{2} y(p)p + k \right) \right\} \\ \text{s.t.} & \quad \frac{1}{2}v(p) - k \geq 0 \\ & \quad \frac{1+x}{2}v(p) - k \geq z \\ & \quad G(z) = x \end{aligned} \tag{\mathcal{P}1'}$$

What keeps the first consumer (i.e., the consumer with $s = 0$) from switching is a pure network externality, whereas the last consumer (with $s = z$) is locked-in by both the network externality (which is now weaker) and switching costs. Here we have to distinguish between two situations. If $\frac{1}{2}v(p) - k \leq \frac{1+x}{2}v(p) - k - z$, then the first constraint implies the second. Then, however, it will be the case that the first consumer is the most difficult to attract, and once this consumer is made to switch, the undercutting firm corners the market, violating the assumption of $x < 1$. Therefore we may safely restrict attention to the opposite case, in which $\frac{1}{2}v(p) - k > \frac{1+x}{2}v(p) - k - z$. In this case it will be increasingly difficult to attract

consumers, implying that there is scope for undercutting equilibria in which only some of the competitor's consumers switch.

Formally, internal solutions may arise iff²¹

$$\frac{1+x}{2}v(p) - k - z = 0 < \frac{1}{2}v(p) - k \quad (13)$$

which, using the fact that $x = G(z) = \frac{z}{\bar{s}}$, can be written

$$v(p) < 2\bar{s} \quad (14)$$

$$k = \frac{1+x}{2}v(p) - x\bar{s} \quad (15)$$

Since $v(p) \leq \frac{1}{2}$, a sufficient condition for internal solutions to be possible is that $\bar{s} \geq \frac{1}{4}$, which is true under the condition in the proposition. Then the constraints $\frac{1}{2}v(p) - k \geq 0$ and $\frac{1+x}{2}v(p) - k \geq z$ can be replaced with the single constraint $k = \frac{1+x}{2}v(p) - x\bar{s}$, which allows us to rewrite our problem as follows:

$$\max_{p,x} \left\{ (1+x) \left(\frac{1+x}{2}y(p)p + \frac{1+x}{2}v(p) - x\bar{s} \right) \right\} \quad (16)$$

Substituting for $v(p)$ and $y(p)$, the maximization problem is to choose $x \in (0, 1)$ and $p \in [0, 1]$ so as to maximize:

$$\pi = (1+x) \left($$

This is a valid solution for x when $\bar{s} \in (\frac{1}{3}, \frac{1}{2})$, hence for this range the undercutting firm chooses $x = -\frac{1-2\bar{s}}{1-4\bar{s}} \in (0, 1)$, sets $p = 0$ and earns

$$\pi = \frac{\bar{s}^2}{4\bar{s} - 1} \quad (22)$$

Undercutting this way is profitable if

$$\frac{\bar{s}^2}{4\bar{s} - 1} \geq \frac{1}{4} \quad (23)$$

which is always true when $\bar{s} \in (\frac{1}{3}, \frac{1}{2})$. For $\bar{s} \leq \frac{1}{3}$ optimal undercutting entails $x = 1$, and $p = 0$. If so, the firm earns $\pi = 1 - 2\bar{s}$. The undercutting is profitable if $1 - 2\bar{s} \geq \frac{1}{4} \iff \bar{s} \leq \frac{3}{8}$ which always holds when $\bar{s} \leq \frac{1}{3}$. Hence, for $\alpha = 0$, no pure-strategy equilibrium with $a = \infty$ can be sustained.

Proof of Proposition 3.

Let us first look at the situation where a firm undercuts by setting $q \geq 1$, which is the rational way to undercut iff $x < 1$. If so, we have that $y(q) = 0 = v(q)$. Consequently, when $\alpha = \frac{1}{2}$ program $(\mathcal{P}1)$ can be simplified as follows:

$$\begin{aligned} \max_{p,k,x} & \left\{ (1+x) \left(\frac{1}{2}y(p)p + \frac{1+x}{4}y(p)p + k \right) \right\} \\ \text{s.t.} & \quad \frac{1}{4}v(p) - k \geq 0 \\ & \quad \frac{1}{2}v(p) + \frac{1}{4}v(p) - k \geq 0 \\ & \quad \frac{1+x}{4}v(p) - k \geq z \\ & \quad \frac{1}{2}v(p) + \frac{1+x}{4}v(p) - k \geq z \\ & \quad G(z) = x \end{aligned} \quad (\mathcal{P}1')$$

Noting that the second and forth constraints follow by the first and third we can write $(\mathcal{P}1')$ as:

$$\begin{aligned} \max_{p,k,x} & \left\{ (1+x) \left(\frac{1}{2}y(p)p + \frac{1+x}{4}y(p)p + k \right) \right\} \\ \text{s.t.} & \quad \frac{1}{4}v(p) - k \geq 0 \\ & \quad \frac{1+x}{4}v(p) - k \geq z \\ & \quad G(z) = x \end{aligned} \quad (\mathcal{P}1'')$$

What keeps the first consumer (i.e., the consumer with $s = 0$) from switching is a pure network externality, whereas the last consumer (with $s = z$) is locked-in

by both the network externality (which is now weaker) and switching costs. Here we have to distinguish between two situations. If $\frac{1}{4}u(p) - k \leq \frac{1+x}{4}u(p) - k - z$, then the first constraint implies the second. Then, however, it will be the case that the first consumer is the most difficult to attract, and once this consumer is made to switch, the undercutting firm corners the market, violating the assumption of $x < 1$. Therefore we may safely restrict attention to the opposite case, in which $\frac{1}{4}u(p) - k > \frac{1+x}{4}u(p) - k - z$. In this case it will be increasingly difficult to attract consumers, implying that there is scope for undercutting equilibria in which only some of the competitor's consumers switch.

Formally, internal solutions may arise iff²²

$$\frac{1+x}{4}v(p) - k - z = 0 < \frac{1}{4}v(p) - k \quad (24)$$

which, using the fact that $x = G(z) = \frac{z}{\bar{s}}$, can be written

$$v(p) < 4\bar{s} \quad (25)$$

$$k = \frac{1+x}{4}v(p) - x\bar{s} \quad (26)$$

Since $v(p) \leq \frac{1}{2}$, a sufficient condition for internal solutions to be possible is that $\bar{s} \geq \frac{1}{8}$, which is true under the condition in the proposition. Then the constraints $\frac{1}{4}v(p) - k \geq 0$ and $\frac{1+x}{4}v(p) - k \geq z$ can be replaced with the single constraint $k = \frac{1+x}{4}v(p) - x\bar{s}$, which allows us to rewrite our problem as follows:

$$\max_{p,x} \left\{ (1+x) \left(\frac{1}{2}y(p)p + \frac{1+x}{4}y(p)p + \frac{1+x}{4}v(p) - x\bar{s} \right) \right\} \quad (27)$$

Substituting for $v(p)$ and $y(p)$, the maximization problem is to choose $x \in (0, 1)$ and $p \in [0, 1]$ so as to maximize:

$$\pi = (1+x) \left(\left(\frac{1}{2} + \frac{1+x}{4} \right) (1-p)p + \frac{1+x}{4} \frac{1}{2} (1-p)^2 - x\bar{s} \right) \quad (28)$$

Maximizing w.r.t. p yields

$$\frac{\partial \pi}{\partial p} = -\frac{1}{4} (1+x) (5p + xp - 2) = 0 \iff p = \frac{2}{5+x} \in \left[\frac{1}{3}, \frac{2}{5} \right] \quad (29)$$

²²Note that in any internal solutions, the constraint $\frac{1+x}{4}u(p) - k \geq z$ must bind (if not, also some consumers with $s > z$ will switch).

However, for p in this range and $\bar{s} \geq \frac{1}{3}$ it is easily verified that

$$\frac{\partial \pi}{\partial x} = \frac{1}{2}p - \frac{3}{4}p^2 - \frac{1}{4}xp^2 + \frac{1}{4} + \frac{1}{4}x - 2x\bar{s} - \bar{s} \leq 0 \quad (30)$$

Consequently, an interior solution is never optimal for the undercutting firm.

Next consider cornering the market. Then there are no reasons not to set $q = 0$, which implies that $y(q) = 1$ and $v(q) = \frac{1}{2}$. Then $(\mathcal{P}2)$ reduces to:

$$\begin{aligned} \max_{p,k} \{ & 2(y(p)p + k) \} \\ \text{s.t.} \quad & \frac{1}{4} + \frac{1}{2} \left(\frac{1}{2}v(p) + \frac{1}{4} \right) - k \geq 0 \\ & \frac{1}{2}v(p) + \frac{1}{2} \left(\frac{1}{2}v(p) + \frac{1}{4} \right) - k \geq 0 \\ & \frac{1}{4} + \frac{1}{2}v(p) - k \geq \bar{s} \\ & \frac{1}{2}v(p) + \frac{1}{2}v(p) - k \geq \bar{s} \end{aligned} \quad (\mathcal{P}2')$$

A closer inspection reveals that the fourth constraint implies the first three constraints. The fourth constraint must therefore bind in optimum:

$$k = v(p) - \bar{s} = \frac{1}{2}(1-p)^2 - \bar{s} \quad (31)$$

Substitution then yields the unconstrained maximization problem:

$$\begin{aligned} & \max_p \{ 2(y(p)p + k) \} \\ = & \max_p \left\{ 2 \left((1-p)p + \frac{1}{2}(1-p)^2 - \bar{s} \right) \right\} \\ = & \max_p \{ 1 - p^2 - 2\bar{s} \} = 1 - 2\bar{s} \end{aligned} \quad (32)$$

Obviously, the firm sets $p = 0$, and earns profit equal to $1 - 2\bar{s}$. Undercutting in this way is profitable iff $1 - 2\bar{s} \geq \frac{3}{8} \iff \bar{s} \leq \frac{5}{16}$. Hence, undercutting is not profitable and the proposed equilibrium is indeed an equilibrium when $\bar{s} \geq \frac{5}{16}$, which is always true when $\bar{s} \in [\frac{1}{3}, \frac{1}{2}]$. QED.

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