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ABSTRACT

Network Competition with Heterogeneous Calling Patterns

by Wouter Dessein

We show how differences in demand and unbalanced call flows affect considerably the pricing strategies of competing telecommunications networks and this both for competition in linear and nonlinear pricing. Differences in demand give also scope for targeted entry. If networks are close substitutes, we show that an incumbent is able to deter such targeted entry on a customer segment which tends to have a net outflow of calls, though this is harder in nonlinear than in linear pricing.

Keywords: Telecommunications, Interconnection, Unbalanced Calling Patterns, Two-way Access, Competition Policy

ZUSAMMENFASSUNG

Netzwettbewerb bei heterogener Nachfrage

In dem Aufsatz wird gezeigt, wie Unterschiede in der Nachfrage und ungleichgewichtige Folgen von Telefonanrufen die Preisstrategien der im Wettbewerb stehenden Anbieter von Telekommunikationsnetzen beeinflussen. Dies gilt für den linearen und nichtlinearen Preiswettbewerb. Unterschiede in der Nachfrage schaffen auch einen Spielraum für bewußte Markteintritte. Wenn Netze enge Substitute sind, dann kann gezeigt werden, daß die eingesessenen Netzanbieter im Stande sind, derartige Markteintritte in Kundensegmente zu verhindern, die durch einen Nettoüberschuß an herausgehenden Anrufen gekennzeichnet sind. Dies ist jedoch bei nichtlinearer Preispolitik schwieriger als bei linearer Preispolitik.

1 Introduction

The telecommunications industry is a fragmented market with a large number of customer segments, typically characterized by different volume demands for calls. Incumbent operators, for example, have in general at least three customer divisions, respectively focussing on the residential, the business and the corporate sector, and also inside these customer categories, especially the residential segment, demand may differ tremendously. A key assumption in the literature on competition between interconnected (telecommunications) networks and two-way access, started by Armstrong (1998) and Laffont, Rey and Tirole (1998a,b), is that the calling pattern is *balanced*: for equal prices, flows in and out of a network are balanced - even if market shares are not. This assumption is very plausible with homogeneous customers; it will for example be satisfied if all customers receive the same amount of calls. Also heterogeneity in outgoing demand does not rule out balanced calling patterns: customers not only differ in outgoing calls, they also receive different volumes of ingoing calls and if there is a perfect correlation, there will be no net flows between different segments for equal prices. This, however, is not observed in reality: though customers who call a lot (*'heavy users'*) effectively tend to receive more calls than people who call only moderately (*'light users'*), evidence indicates that call flows between different customer categories are often considerably unbalanced. In aggregate data of a European country,[1] business or corporate customers call during peak time 10% more to residential customers than the other way round. As here light users tend to be called up more than they call, we denote this by *a light biased calling pattern.* Surprisingly, the opposite holds for call flows between (small) business firms and (large) corporate firms. In our data, business firms call 20% more to corporate firms than vice versa. Similarly, off peak, residential customers have a net outflow of calls of the same order to the corporate/business segment.[2] These are cases where heavy users tend to receive more calls then they originate, which we denote by *a heavy biased calling pattern.*

To incorporate these features of the industry, this paper generalizes the basic model of competition between interconnected networks, as developed in Laffont Rey and Tirole (1998a,b) (LRT hereafter), and shows how operators optimally adjust their strategies and pricing schedules in response to such *heterogeneous calling patterns.* LRT present a duopoly model in which customers must decide which network to join and given this choice, how much to call. Per call that terminates off-net, an operator pays a - regulated or negotiated - access charge to its rival. It is assumed that reciprocal access pricing, that is the equality of the interconnect prices charged by the two networks, is mandated. Whereas in LRT, customers are identical, we explicitly model differences in outgoing calls by

[1] We are unable to disclose more information.

[2] Note that one cannot aggregate peak and off peak call flows, as firms charge different prices to customers and pay a different access charge to each other.

assuming that customers are either *heavy* (call a lot) or *light users*. Moreover, to capture the wide variety of calling patterns observed in reality, we allow for *heavy-biased, light-biased* and *balanced calling patterns*. Our findings are summarized below.

A central result in the literature on two-way access is that, under linear pricing, the access charge may be used as an instrument of collusion due to a raise-each-other's-cost effect: for given market shares, the average perceived marginal cost of a call increases with the access charge so that a higher access charge induces the networks to set a higher retail price. We show that if calling patterns are unbalanced, a *new (collusive) effect of the access charge* arises, which may add to or go against the standard raise-each-other's-cost effect. Crucial to our argument is that heavy users are more price-sensitive in the choice of their network: since the benefit of a low usage price is larger for customers who call a lot, relatively more heavy users will accept not being connected to their preferred network for a given price differential. As a result, a low price creates a bias in the 'customer portfolio' of a network towards relatively more heavy users; there is an endogeneous selection of customers. A first consequence of this is that competition is tougher and the equilibrium price is lower when the average size of customers is higher, or, keeping this average size fixed, when customers are more heterogeneous. Secondly, whether heavy users or whether light users call more than they are called changes considerably the impact of the access charge on competition. Suppose that heavy users call more than they are called for equal prices (light biased calling pattern), then an increase in the access charge lowers the incentives to cut prices, as a low price attracts in the first place heavy users. Compared with a balanced calling pattern, a high access charge thus has a bigger collusive effect. The opposite holds when heavy users receive more calls than they originate (heavy biased calling pattern). An increase in the access charge then has two opposite effects: on the one hand, the unbalanced call flows make a price cut more profitable so that competition becomes tougher, on the other hand, a higher access charge softens competition through the raise-each other's cost effect. We show that the unbalancedness effect prevails, and thus the equilibrium price decreases with the access charge, if networks are close substitutes and/or elasticity is small. If networks are bad substitutes or the elasticity is large, an increase in the access charge still boosts the equilibrium price, but its impact is smaller compared to a balanced calling pattern.

Our companion paper Dessein (1999) has stressed that the collusive power of the access charge which results from the raise-each-other's-cost effect crucially depends on the assumption of linear pricing. A similar result holds here: if networks compete in nonlinear prices, the unbalancedness effect disappears and neither access charges nor calling patterns affect average profits. Intuitively, in contrast with a high quantity, which is valued more by a heavy user, a low tariff is worth as much to a heavy as to a light user, so that the endogeneous selection of customers, crucial to our result, disappears. This, however, is only true when all

customers perceive the substitutability of the networks identically. If customers who tend to have a net outflow of calls perceive the networks as better substitutes, a lower fixed fee attracts in the first place these customers. By agreeing on a high access charge, low fixed fees are then discouraged. Similarly, if the customers with a net outflow perceive the networks as more differentiated, networks may increase profits by agreeing on a low access charge.

Whether or not unbalanced calling patterns affect profits under nonlinear pricing, they definitely change the way networks compete for customers. First, when networks can discriminate explicitly, they make higher profits - including access revenues - on customers generating an access deficit than on those yielding access revenues. Intuitively, competition is very tough for customers generating access revenues, as, ceteris paribus, these customers are not only profitable to have, they are also very costly *not to have,* since they then join the rival operator. Secondly, we show that the calling pattern affects considerably the way networks implicitly have to discriminate between customers of different types. Since the tariff which a customer pays depends to a large extent on the net outflow or inflow generated by him, calling patterns have an important impact on incentive conditions: for a given access charge, the incentive constraint of the light users may be binding, the incentive constraint of the heavy users may be binding or the equilibrium may be the same as with explicit price discrimination.

Finally, we study the impact of unbalanced calling patterns on the profitability of entry and the opportunities for entry deterrence by an incumbent operator. We show that if the entrant's coverage is not random, but it targets markets (cities, businesses) which tend to have a net outflow of calls, the incumbent can, under *linear pricing*, enjoy monopoly profits while deterring entry with high access charges if the entrant is not too differentiated from the incumbent; a sufficient condition for this is that the target group calls more than it is being called as long as the entrant does not price himself out of the market. Under *nonlinear pricing*, entry deterrence is harder as the entrant then can set a high usage fee in order to rebalance in and outflow, while compensating his clients for this by a low fixed fee. It turns out that a necessary condition to deter entry is that the incumbent's profits are lower than some upperbound, which is, except for very unbalanced calling patterns, very small. As a result, the incumbent often prefers to accommodate entry.

This paper is organized as follows. Section 2 describes our model of heavy and light users. Section 3 investigates competition in linear prices in the mature phase of the industry and derives a general solution for it. The particular impact of customer heterogeneity and unbalanced calling pattern is analyzed in section 4. Optimal nonlinear tariffs are analyzed in section 5. Targeted entry and conditions for the existence of cornered market equilibria are investigated in section 6. Section 7 concludes.

2 A model of heavy and light users

We consider the competition between two horizontally differentiated networks. The main elements are as follows:

Cost structure: The two networks have the same cost structure. Serving a customer involves a fixed cost f. Per call, a network also incurs a marginal cost c_o at the originating and terminating ends of the call and a marginal cost c_1 in between. The total marginal cost is thus

$$c = 2c_o + c_1$$

Demand structure: The networks are differentiated à la Hotelling. Consumers are uniformly located on the segment $[0, 1]$ and networks are located at the two extremities, namely at $x_1 = 0$ and $x_2 = 1$. Given income y and telephone consumption q, a type $k-$consumer located at x joining network i has utility:

$$y + u_k(q) + v_o - \tau |x - x_i|$$

where v_o represents a fixed surplus from being connected,[3] $\tau |x - x_i|$ denotes the cost of not being connected to its "most preferred" network, and the variable *gross surplus,* $u_k(q)$, is given by:

$$u_k(q) = \frac{k^{\frac{1}{\eta}} q^{1-\frac{1}{\eta}}}{1 - \frac{1}{\eta}}$$

which yields a constant elasticity demand function:

$$u_k'(q_k) = p \Leftrightarrow q_k = kp^{-\eta} \equiv kq(p)$$

We assume that the elasticity of demand, η, exceeds 1. Under uniform pricing, the variable *net* surplus is then:

$$v_k(p) = \max_q \{u_k(q) - pq\} = k \left(\frac{p^{-(\eta-1)}}{\eta - 1} \right) \equiv kv(p)$$

We consider two different customer types or customer segments:

- *light users*, fraction μ of the market, characterized by $k = k_L$.
- *heavy users*, fraction $1 - \mu$ of the market, characterized by $k = k_H > k_L$.

[3] We will assume throughout the paper that v_o is "large enough", so that all consumers are always connected in equilibrium.

The distribution of customers on the segment $[0,1]$ is assumed to be independent of their type k. Letting

$$k = \mu k_L + (1-\mu)k_H$$

denote the average type of customers, we introduce an *index of heterogeneity in demand, h*, given by:

$$h = \frac{var\ k_i}{k^2} = \frac{\mu(k_L)^2 + (1-\mu)(k_H)^2}{k^2} - 1$$

It follows directly that $h > 0$ if and only if $k_L \neq k_H$

Calling patterns: We suppose that a fraction ℓ of calls terminates on the light user segment, where ℓ is independent of the type of customer who originates the call. We later allow for *narcissistic* calling patterns in which customers call relatively more customers of the same type. As it is natural that identical customers receive the same amount of calls, we assume that ℓ equals μ if $k_H = k_L$, but may vary with $\Delta k \equiv k_H - k_L$. E.g., ℓ is likely to decrease with Δk. As a benchmark, we are interested in the case where ℓ is such that the calling pattern is balanced:

Definition 1 *A calling pattern is balanced whenever for equal usage fees, each customer calls as much as he is being called.*

With homogeneous customers, this is realized very naturally by our assumption that identical customers receive the same amount of calls ($\ell = \mu$). With heterogeneous customers, a different assumption is needed:

Lemma 1 *A calling pattern is* balanced *if and only if* $\ell = \dfrac{\mu k_L}{k}$

Proof. For equal usage fees, a light user receives the same amount of calls as he originates if and only if

$$\ell\left[\mu k_L q(p) + (1-\mu)k_H q(p)\right] = \mu k_L q(p) \Leftrightarrow \ell = \frac{\mu k_L}{k}$$

By construction, the same holds for heavy users. ■

Given that customers differ in their volume demand, the assumption of a balanced calling pattern is quite strong and often violated in reality. We therefore allow ℓ to be different from $\mu k_L/k$, which yields two types of unbalanced calling patterns:

Definition 2 *A calling pattern is:*

- light biased *if* $\ell > \mu k_L/k$: *Light users then receive more calls than they originate for equal prices.*

- heavy biased *if* $\ell < \mu k_L/k$: *Heavy users then receive more calls than they originate for equal prices.*

An *index of unbalancedness* is given by

$$\psi = \frac{\Delta k}{k}\left(\frac{\mu k_L}{k} - \ell\right).$$

We have that $\psi = 0$ for a balanced calling pattern, while $\psi < 0$ for a light biased calling pattern and $\psi > 0$ for a heavy biased calling pattern.

3 Price competition

For given prices p_1 and p_2, market shares are determined as in Hotelling's model. A consumer of type s ($s = L, H$) located at $x = \alpha_s$ is indifferent between the two networks if and only if

$$k_s v(p_1) - \tau\alpha_s = k_s v(p_2) - \tau(1 - \alpha_s),$$

As a result, the market share of network 1 in a segment with customers of type s equals

$$\alpha_s = \alpha_s(p_1, p_2) \equiv \frac{1}{2} + k_s\sigma\left[v(p_1) - v(p_2)\right]$$

where

$$\sigma \equiv \frac{1}{2\tau}$$

is an index of substitutability between the two networks. As long as $\alpha_s \in]0, 1[$, $(s = L, H)$, network i's *overall market share*, $(i = 1, 2)$, is given by

$$\alpha_i = \alpha_i(p_i, p_j) \equiv \frac{1}{2} + k\sigma\left[v(p_i) - v(p_j)\right]. \tag{1}$$

Given our assumptions about the calling pattern, the *share in the volume of incoming calls* of network 1 and 2 are

$$\hat{\alpha}_1 = \alpha_L\ell + \alpha_H(1 - \ell), \quad \text{and} \quad \hat{\alpha}_2 = 1 - \hat{\alpha}_1 \tag{2}$$

which, using the index of unbalancedness and heterogeneity, can be rewritten as

$$\hat{\alpha}_i = \hat{\alpha}_i(p_i, p_i) \equiv \frac{1}{2} + (1 + h + \psi)k\sigma\left[v(p_i) - v(p_j)\right]. \tag{3}$$

Let a denote the unit access charge to be paid for interconnection by a network to its competitor. Network 1's profits are given by

$$\begin{aligned}\pi_1(p_1, p_2) \;=\; & \mu\alpha_L\left[(p_1 - c - \hat{\alpha}_2(a - c_o))k_L q(p_1) - f\right] + \\ & (1 - \mu)\alpha_H\left[(p_1 - c - \hat{\alpha}_2(a - c_o))k_H q(p_1) - f\right] + \\ & \hat{\alpha}_1\left[(1 - \alpha_L)\mu k_L + (1 - \alpha_H)(1 - \mu)k_H\right](a - c_o)q(p_2),\end{aligned} \tag{4}$$

These profits can be decomposed into a *retail profit*

$$\alpha_1^v k(p_1 - c)q(p_1) - \alpha_1 f \equiv \alpha_1^v kR(p_1) - \alpha_1 f$$

which would be made if all calls terminated on net, plus an *access revenue,*

$$A_1 = \hat{\alpha}_1 \alpha_2^v (a - c_o)kq(p_2) - \alpha_1^v \hat{\alpha}_2 (a - c_o)kq(p_1),$$

where α_i^v is a *volume-adjusted market share* in which a higher weight is given to customers with a higher volume type:

$$\alpha_1^v = \alpha_L \frac{\mu k_L}{k} + \alpha_H \frac{(1-\mu)k_H}{k}, \quad \alpha_2^v = 1 - \alpha_1^v$$

or

$$\alpha_i^v = \alpha_i^v(p_i, p_j) \equiv \frac{1}{2} + (1+h)k\sigma\left[v(p_i) - v(p_j)\right] \tag{5}$$

It is interesting to note its relation with α_i and $\hat{\alpha}_i$. When $p_i = p_j$, all market shares equal $\frac{1}{2}$. When $p_i < p_j$, $\alpha_i^v > \alpha_i$, while then $\alpha_i^v > \hat{\alpha}_i$ if and only if $\psi < 0$ (light biased calling pattern).

In any shared market equilibrium, the first order conditions with respect to p_i and p_j must be satisfied. Rewriting these conditions, we find that any shared market equilibrium (p_i, p_j) satisfies

$$\frac{p_i - (c + \hat{\alpha}_j(a - c_o))}{p_i} = \frac{1}{\eta}\left[1 - \frac{k\sigma}{\alpha_i^v}(R + A)\right] \tag{6}$$

with

$$\begin{aligned} R &\equiv (1+h)R(p_i) - f \\ A &\equiv (a - c_o)\left[(1 + h + \psi)(\hat{\alpha}_i q_i + \hat{\alpha}_j q_j) - (1+h)(\alpha_i^{iv} q_j + \alpha_j^{iv} q_i)\right] \end{aligned}$$

Equation (6) admits a comparison with the standard monopoly pricing formula $((p^M - c)/p^M = 1/\eta)$. The first difference is that each network's marginal cost must account for the access premium on off net calls, and is equal to $c + \hat{\alpha}_j(a - c_o)$ on average. The second difference with the standard monopoly formula is due to the impact of price on the market share and the composition of the customer portfolio. This affects both retail revenues and access revenues. The effect of *competition for access revenues or market share in the volume of incoming calls*, A, is discussed further in the paper. The effect of *competition for retail revenues or market share in outgoing volume*, R, can be described as follows: Each unit price increase lowers customer market share by $\sigma k q_i$ and the volume-adjusted market share α_i^v by $\sigma k q_i(1+h)$. This implies a net loss in retail revenues of $\sigma k q_i \left((1+h)R(p_i) - f\right)$. The higher this retail revenue loss, the more reluctant networks are to set high prices. This difference with the standard monopoly formula (which does not take the effect of competition for market share into

account), however, is smaller when the network has a larger volume-adjusted market share. The substitutability σ is divided by $\hat{\alpha}_i$ in formula (6): a firm with a large number of customers has less incentive to lower its price as otherwise retail profits on the existing customer base would decrease too much in absolute terms.

The following proposition characterizes the equilibrium when the access charge and/or the substitutability of the networks is not too large:

Proposition 1 *(i) For a close to c_o, there exists a unique equilibrium, which is symmetric and characterized by $p_1 = p_2 = p^*$, given by:*

$$\frac{p^* - (c + \frac{a - c_o}{2})}{p^*} = \frac{1}{\eta}\left(1 - 2\sigma\left[(1+h)kR(p^*) - f + \psi kq(p^*)(a - c_o))\right]\right) \qquad (7)$$

with $R(p^*) \equiv (p^* - c)q(p^*)$

(ii) If the access charge is such that $p^R > \frac{\eta}{\eta - 1}\left(c + \frac{a - c_o}{2}\right) \geq p_R$, where p^R is the largest and p_R the lowest price satisfying the budget constraint $kR(p) = f$, then for σ small, there exists a unique equilibrium, which is symmetric and characterized by $p_1 = p_2 = p^*$, as above.

Proof. The proof is an extension of the proof of Proposition 1 in Laffont et al. 1998a and is available upon request. ■

4 Heterogeneity in demand and unbalanced calling patterns

We now analyze more in detail the competitive outcome characterized by equation (7). We first assess the impact of differences in volume demand, assuming a balanced calling pattern, and then study the effect of unbalanced calling patterns. Central in our analysis is that heavy users are more price-sensitive in the choice of their network: since they benefit more from a low price, they more easily accept not being connected to their preferred network for a given price differential.[4] A first consequence is that competition is tougher with only heavy users than with only light users: an increase in the average type of customers leads to a lower equilibrium price. Secondly, a low price-network will have a relatively high fraction of heavy users among its clientele: there is an *endogeneous selection of customers*. As a consequence, competition is tougher than what the 'average' size of users may suggest: all other things equal, the equilibrium price is lower

[4]While this comes very natural out of our Hotelling framework, it is consistent with the widely observed fact that high volume customers are quickest to switch to lower price alternatives.

when customers are more heterogeneous in demand. Finally, if calling patterns are moreover unbalanced, this endogeneous selection also changes the impact of the access charge on the equilibrium price.

4.1 Heterogeneity in demand

With a *balanced calling pattern*, the composition of a network's clientele has no direct effect on the access deficit, as for equal prices heavy and light users make as many calls as they receive. However, as argued above, a higher average size of customers k or an increase in the heterogeneity of demand (measured by h) results in tougher competition: setting $\psi = 0$ in equation (7), the equilibrium price is characterized by

$$\frac{p^* - (c + \frac{a - c_o}{2})}{p^*} = \frac{1}{\eta}\left(1 - 2\sigma\left[(1+h)kR(p^*) - f\right]\right) \tag{8}$$

Remark that the effect of a higher average size can be perfectly mimicked by an increase in heterogeneity: only the product $k(1+h)$ matters.

Proposition 2 *Keeping average demand constant, an increase in the heterogeneity of volume demand lowers the equilibrium price. Similarly, keeping heterogeneity in demand constant, an increase in average demand results in tougher competition.*

Proof. See appendix 8.1 ■

While heterogeneity in demand affects the price level in equilibrium, the impact of the access charge on competition is unchanged. Indeed, condition (8) is the same as for homogeneous customers (see LRT), excepted that the relevant revenue function, $kR(p)$, is now multiplied by $(1+h)$. It follows that, although competition is tougher for a given access charge with heterogeneous customers, the access charge is still an instrument of collusion: as long as the equilibrium $p_1 = p_2 = p^*$ exists, p^* increases with a. Laffont-Tirole (1999) call this the *raise-each-other's-cost effect.* Each network's perceived average marginal cost, $c + (a - c_o)/2$, increases with the access charge, leading to a higher equilibrium price. A corollary is that a regulator should set the access charge below c_o in order to enhance competition (under the constraint that networks still break even).

4.2 Unbalanced calling patterns

Unlike heterogeneity in demand, unbalanced calling patterns have no effect on the price level in the absence of an access markup: for $a = c_o$, the equilibrium price is still given by (8). But competition is affected by the nature of the calling pattern as soon as the access charge differs from the termination cost ($a \neq c_o$),

because the composition of a network's customer portfolio now also affects access revenues. Let us suppose first that $a > c_o$ and the calling pattern is *light biased* ($\psi < 0$). Heavy users then have a *negative impact* on the access revenues since they tend to call more than they are called. A cut in the usage price is thus also less profitable, as it attracts especially these heavy users. Note that this 'stealing' of heavy users induces not only a *direct cost,* as the network must pay for the net outflow of calls, but also gives way to an *opportunity cost,* as the network foregoes the net access revenues that would have been made if these heavy users were subscribed to the rival network. Compared to the balanced calling pattern benchmark, an access markup thus has a *bigger collusive effect:* it further reduces incentives to set low prices. This is clearly shown by equation (7): as compared with the case of a balanced calling pattern ($\psi = 0$), for a light biased pattern ($\psi < 0$), the equilibrium price further increases with the access mark-up ($a - c_o$). Similarly, an access subsidy ($a < c_o$) has a *larger pro-competitive* effect.

A polar picture is obtained if heavy users receive more calls than they originate, that is, if there is a *heavy biased calling pattern* ($\psi > 0$). For $a > c_o$, heavy users then have a *positive effect* on the access deficit and, as a result, the effect of the access markup on the equilibrium price is ambiguous: on the one hand, the access markup still reduces incentives to lower prices through the *raise-each-other's-cost effect*; on the other hand, lowering prices attracts in the first place heavy users, which are now good for the access deficit so that the access markup also encourages price cuts.

Define $\tilde{p}$ as the equilibrium price when $a = c_o : \tilde{p} = p^*_{\mid a=c_o}$. From (7), $\tilde{p}$ is independent of ψ.

Proposition 3 *Compared with the case of a balanced calling pattern, for a close to c_o, the impact of an increase in the access charge on the equilibrium price is:*

- *even more positive when the calling pattern is biased towards light users.*
- *still positive but smaller when the calling pattern is biased towards heavy users and*
$$4\sigma \cdot \psi \cdot k\tilde{p}q(\tilde{p}) < \eta, \tag{9}$$
- *reversed (negative) when the calling pattern is biased towards heavy users and*
$$4\sigma \cdot \psi \cdot k\tilde{p}q(\tilde{p}) > \eta. \tag{10}$$

Proof. See appendix 8.1 ■

Conditions (9) and (10) suggest that the *raise-each-other's-cost effect* becomes relatively less important as demand gets more inelastic. Intuitively, in the limit case in which $\eta = 0$ (demand per customer is constant), the marginal cost of a good does not affect the equilibrium price in an oligopoly. The collusive (or pro-competitive) effect of the access charge then only stems from unbalanced calling

patterns: for $\eta = 0$, p^* is independent of the access charge with a balanced calling pattern, while p^* increases (decreases) with the access charge when there is a light biased (heavy biased) calling pattern.[5] The *impact of unbalanced calling patterns*, for its part, will be stronger the higher the unbalancedness and the larger the substitutability. For a given price cut, the effect on the composition of the customer's portfolio is larger if the substitutability is high, as customers then switch faster. While for $\sigma = 0$, even a huge price change does not affect the mix of heavy and light users and the unbalancedness effect disappears, for σ very large, a price cut by an ε may attract almost all heavy users (and still leave a lot of light users to the rival network). Consequently, while for σ small, an increase in the access charge may boost prices with a heavy biased calling pattern, for σ large enough, the impact of unbalancedness prevails and an access markup induces tougher competition.

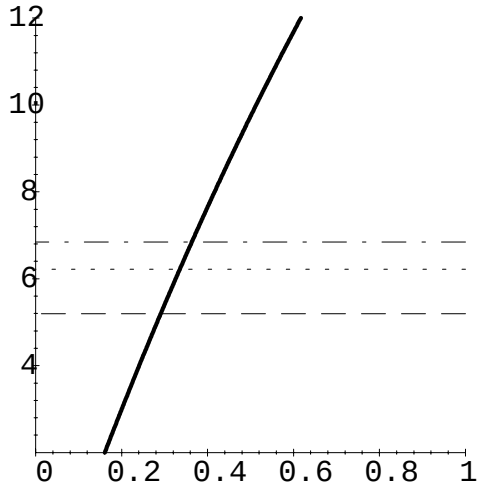
We illustrate the relative importance of both effects with a numerical example. Figure 1 shows equilibrium profits[6] as a function of ℓ, respectively for $\sigma = 8$ (left figure) and $\sigma = 2$ (right figure). Other parameter values are $\eta = 2$, $f = 0$, $c = 1$, $\mu = \frac{1}{2}$ and $k_H = 2k_L = 2$. It follows that $\psi = \frac{1}{3} - \ell$ and thus a calling pattern is light biased ($\psi < 0$) if and only if more than 1/3 of all calls terminate on the light users' segment. The index of heterogeneity, h, equals 1/9. For a given light biased calling pattern ($\ell = 1/2$) the *raise-each-other's cost* (RC) effect of an access markup is given by bc, as this is the increase in profits that would have occurred with a balanced calling pattern. The *unbalancedness* (UB) effect is given by cd, as this is the increase in profits due to the presence of a light biased calling pattern. A higher substitutability has a large impact on the relative importance of both effects. While for $\sigma = 8$ (left figure), $bc < cd$ and the UB-effect is far more important than the RC-effect, if $\sigma = 2$ (right figure), $bc > cd$ so that the RC-effect is largest. A similar result is obtained with heavy biased calling patterns ($\ell < 1/3$). The UB-effect then goes against the RC-effect, where the UB-effect prevails (and profits decrease with a) if ℓ is smaller than some critical value L. Again, we see that an increase in the substitutability raises the importance of the UB-effect relative to the $RC-$effect: for $\sigma = 8$, profits decrease with a for much larger values of ℓ than for $\sigma = 2$.

[5] Suppose e.g. that consumers have a constant demand $q(p) = k$ ($k = k_L, k_H$) and assume for simplicity that $f = 0$, then the equilibrium price is given by

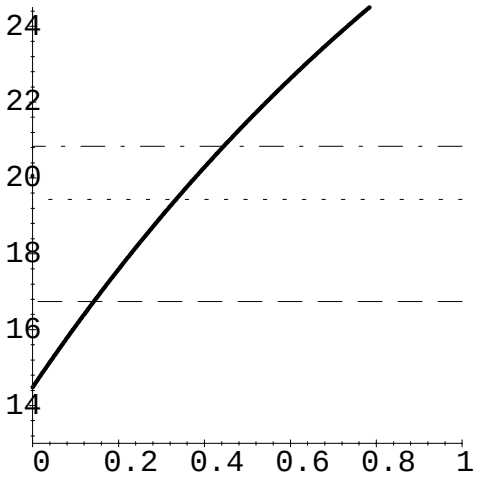
$$p^* - c = \frac{1}{(1+h)} \left[\frac{1}{2\sigma k} - \psi(a - c_o) \right].$$

[6] Multiplied by 100.

Profits as a function of ℓ ($\sigma = 8$)



Profits as a function of ℓ ($\sigma = 2$)



$a = c_o$

$a - c_o = 0.2$

$a - c_o = 0.2$, balanced calling pattern ($\ell = 1/3$)

$a - c_o = 0.2$, balanced cp ($\ell = 1/3$) and homogeneous customers

To conclude this section, we discuss the global impact of heterogeneous calling patterns on the equilibrium price for a given access charge (let us assume $a \geq c_o$). It is straightforward from the previous propositions that customer heterogeneity always toughens competition if the calling pattern is balanced or heavy biased. With a light biased calling pattern, prices are also lower for $a = c_o$, but a markup on access then has a larger collusive effect. Whereas by continuity, competition is still tougher with heterogeneous customers for a close to c_o, this is not necessarily true for larger values of a. To have a sense of which factor will dominate, we analyze how the access charge which implements the monopoly price p^M is affected. It follows from (7) that this access charge, a^M, is given by

$$\frac{a^M - c_o}{2} = 2\sigma(p^M - c)\left(\frac{(1+h)kR(p^M) - f}{1 - 4\sigma k\psi R(p^M)}\right) \tag{11}$$

With homogeneous customers, $h = \psi = 0$, whereas with heterogeneous customers and a light biased calling pattern, $h > 0$ and $\psi < 0$. It follows thus from (11) that for substitutabilities above a critical threshold σ',[7] a^M will be lower with heterogeneous customers, that is the effect of unbalancedness prevails, while for

[7] In order to preserve existence, this threshold σ' cannot be too large, that is, ψ must not be too small compared to h. As a stylized example, consider a pizza-economy in which the pizza-firm segment (μ) is very small but receives all the calls (customers only call to order pizzas),

small values of σ, the effect of heterogeneity in volume demand is more important and a larger access charge is needed to implement p^M.[8] This suggests that a higher substitutability increases the collusive impact of a light biased calling pattern relative to the pro-competitive impact of the associated heterogeneity in demand.

We illustrate this intuition with the same numerical example as above. The line in dashes and dots shows profits when $a - c_o = 0.2$ and customers are homogeneous, that is $k_L = k_H = k = 1.5$ (and thus $h = 0$). As argued above, customer heterogeneity (in the example, $h = 1/9$) always lowers equilibrium profits with a heavy biased or balanced calling pattern ($\ell \leq 1/3$), but a sufficiently light biased calling pattern raises prices again above their 'homogeneous' level. If $\sigma = 8$, this is the case for $\ell > H$; if $\sigma = 2$, for $\ell > H'$. As $H < H'$, we can conclude that an increase in the substitutability raises the (collusive) impact of a light biased calling pattern relative to the pro-competitive effect of the associated heterogeneity.

4.3 Narcissistic calling patterns

We have so far assumed that the fraction of calls terminating on a specific segment is independent of the type of the caller. In reality, however, customers often have a tendency to call relatively more customers of the same type. A convenient way to model such *intra-group biases* is to assume that for a fraction ϕ of all calls, customers behave in a *narcissistic* way, that is they only call customers of their own type; for the other calls, they have the same calling pattern as before. Sticking to our previous notation, the access revenue of network 1 (access deficit of network 2) is then given by:

$$\begin{aligned} A_1 &= (1-\phi)(a-c_o)k\left[\hat{\alpha}_2\alpha_1^{iv}q(p_2) - \hat{\alpha}_1\alpha_2^{iv}q(p_1)\right] + \\ &\quad \phi(a-c_o)\left[q(p_2)-q(p_1)\right]\left[\mu k_L\alpha_1^L\alpha_2^L + (1-\mu)k_H\alpha_1^H\alpha_2^H)\right] \end{aligned} \tag{12}$$

where α_i^{iv} now denotes the market share in incoming volume of non-narcissistic calls. Note that retail profits are unaffected by the calling pattern. The symmetric equilibrium price p^* is then given by

$$\frac{p^* - (c + \frac{a-c_o}{2})}{p^*} = \frac{1}{\eta}\left(1 - 2\sigma\left[(1+h)kR(p^*) - f + \hat{\psi}kq(p^*)(a-c_o)\right]\right)$$

while owners of pizza-firms are light users. Then h goes to zero when μ becomes smaller and smaller, while $|\psi|$ is bounded below by $1 - k_L/k$. As a consequence, $|\psi/h|$ grows without bound and σ' becomes arbitrarily close to 0. Moreover, for σ small, a^M decreases as σ decreases and existence can thus be assured for $a = a^M$ and $\sigma = \sigma' + \varepsilon$.

[8] To make this result more concrete, let us assume $f = 0$ and a light biased calling pattern, which is such that each customer has the same probability of being called, thus $\ell = \mu$. As a result, we always obtain $|\psi| = h$. Substituting in (11), it follows that a^M is an increasing function of heterogeneity as long as $kR(p^M) < 1/4\sigma$. The latter will also be a sufficient condition for $|\psi|$ smaller than h.

with $\hat{\psi} = (1-\phi)\psi$. As a consequence, the previous propositions remain valid under a narcissistic calling pattern: the fact that customers call more to their own type reduces the unbalancedness of flows, but the unbalancedness itself and its direction are preserved. The closer ϕ comes to 1, however, the smaller the differences between a particular heavy- and light-biased calling pattern.

5 Nonlinear tariffs

A surprising result of LRT is that once networks compete in two-part tariffs[9], profits are independent of the access charge. Our companion paper, Dessein (1999), has extended this result to the case where customers are heterogeneous and pricing schedules are used to discriminate implicitly between customers of different types. Though profits are then still independent of the access charge, it is shown that an access markup considerably affects the way networks discriminate implicitly: whereas for $a = c_o$ the equilibrium is the same as with explicit price discrimination (incentive constraints are not binding) and networks make the same profit on heavy and light users, if $k_H - k_L$ is small enough, an access markup makes the incentive constraint of the light users binding and networks make less profits on light than on heavy users. In this section, we show how unbalanced calling patterns also affect substantially the way networks compete in nonlinear pricing.

5.1 Standard model

Competition in optimal nonlinear tariffs is investigated under the restriction that networks cannot price discriminate *explicitly* according to whether a customer is a heavy or a light user (that is, we consider second-degree price-discrimination but rule out third-degree price discrimination). From the revelation principle, networks cannot do better than offering customers the choice between a quantity q_L for a tariff t_L or a quantity q_H for a tariff t_H, where $\{q_L, t_L, q_H, t_H\}$ are such that the heavy users opt for (q_H, t_H) and the light users choose (q_L, t_L). Given q'_L, t'_L, q'_H, t'_H, the tariffs and quantities offered by the rival network, a network maximizes

$$\pi = \mu\alpha_L \left[t_L - cq_L - f\right] + (1-\mu)\alpha_H \left[t_H - cq_H - f\right] + A$$

under the incentive conditions (IC)

$$w_H = w(k_H, q_H, t_H) \geq w(k_H, q_L, t_L) \tag{13}$$
$$w_L = w(k_L, q_L, t_L) \geq w(k_L, q_H, t_H) \tag{14}$$

[9] Which are optimal in their model as customers are homogenous.

where

$$w(k,q,t) \equiv u_k(q) - t,$$

A is the access revenue:

$$\begin{aligned} A \;\equiv\; & \left[\mu(1-\alpha_L)q'_L + (1-\mu)(1-\alpha_L)q'_H\right]\left[\ell\alpha_L + (1-\ell)\alpha_H\right](a-c_o) \\ & - \left[\mu\alpha_L q_L + (1-\mu)\alpha_H q_H\right]\left[\ell(1-\alpha_L) + (1-\ell)(1-\alpha_H)\right](a-c_o), \end{aligned}$$

and α_L, α_H are the market shares of the network respectively in the heavy and the light user segment.

$$\alpha_s = \frac{1}{2} + \sigma\left(w_s - w'_s\right), \quad s = L, H$$

Proposition 4 *i) In a symmetric equilibrium, profits are independent of both the access charge and the calling pattern, and are equal to* $1/4\sigma$.

ii) Fix the average customer type k *and let the difference* $\delta = k_H - k_L$ *vary. For any* δ_o, *there exists an access charge* $a_o > c_o$ *such that a symmetric equilibrium always exists for* $a \leq a_o$, $0 \leq \delta \leq \delta_o$ *and* $\ell \in [0,1]$. *Moreover*

- *Given* $\delta \in]0, \delta_o]$, *for* a *close to* c_o *and/or* ℓ *close to* $\frac{1}{2}\left(\frac{\mu k_L}{k} + \mu\right)$, *incentive constraints are nonbinding and the equilibrium is the same as if networks could explicitly discriminate between heavy and light users:*

$$q_s^* = \hat{q}_s \equiv k_s q(c + \tfrac{a-c_o}{2}),$$

$$\begin{aligned} t_L^* &= \hat{t}_L \equiv 1/2\sigma + f + c\hat{q}_L - 2A_L, \\ t_H^* &= \hat{t}_H \equiv 1/2\sigma + f + c\hat{q}_H - 2A_H, \end{aligned}$$

  where A_L *and* A_H *are respectively the access revenues per light user and heavy user, which satisfy* $\mu\alpha_L A_L + (1-\mu)\alpha_H A_H = 0$. *Per customer profits, given by* $t_s^* + A_s - f - cq_L^*$, *are thus higher on customers causing an access deficit* ($A_s < 0$) *than on customers procuring access revenues.*

- *Given* $a \in]c_o, a_o]$, *for* δ *close* 0,

  - *the IC of the light users is binding if* $\ell < \frac{1}{2}\left[\frac{\mu k_L}{k} + \mu\right]$, *that is with a heavy biased, balanced or slightly light biased calling pattern.*
  - *the IC of the heavy users is binding if* $\ell > \frac{1}{2}\left[\frac{\mu k_L}{k} + \mu\right]$, *that is with a substantially light biased calling pattern.*

Proof. See appendix 8.2.1 ■

Just as the standard raise-each-other's cost effect has no impact on profits when networks compete in nonlinear pricing, the unbalancedness effect, highlighted in the previous section, disappears completely: profits are independent of the access charge and the calling pattern. Intuitively, under linear pricing, the only way networks can compete for market share is with the usage fee. Since heavy users value more a lower usage price than light users, a price cut affects in the first place the market share in the heavy user segment, there is an endogeneous selection of customers. The latter disappears under nonlinear pricing as networks then use tariffs in order to compete for market share: in contrast with a high quantity, which is valued more by a heavy user, a low tariff is worth as much for a heavy as for a light user. It follows that the collusive (pro-competitive) effect of unbalanced calling patterns, which stems from this endogeneous selection of customers, also disappears. Further, we will show how an endogeneous selection of customers arises again when customers of different types perceive the substitutability of networks in a different way. Collusion may then again be possible.

While unbalanced calling patterns do not alter networks' aggregate profits, they affect the way networks compete for customers. First, unbalanced calling patterns affect the explicit price discrimination equilibrium: in contrast with a balanced calling pattern, profits per customer differ from $1/2\sigma$ and, surprisingly, higher profits are made on customers who are at first sight less profitable. Second, the calling pattern affects whether and which incentive constraints are binding in equilibrium.

Consider first the case of explicit price discrimination. Given the equilibrium quantities, competition in tariffs is then very similar to the one in a symmetric Hotelling model with unit demands: the good offered to customers is here the subscription to a network, the gross utility of it is determined by the offered quantities. In the Hotelling model, the tariff must trade-off between maximizing (retail-)profits per customer and market share. In the case of competition between networks, firms face the same trade-off, but must also take the impact of the tariff on access revenues into account. In equilibrium, the cost to a network of a tariff cut needed to increase its market share on the heavy user segment by ε, equals $\mu\alpha_H\varepsilon/\sigma$. The benefits are the extra retail profits, $\varepsilon\mu R_H$, plus the change in access revenues $\varepsilon\partial A/\partial\alpha_H$. As a result, retail profits per heavy user are

$$R_H = \frac{\alpha_H}{\sigma} - \frac{1}{1-\mu}\frac{\partial A}{\partial \alpha_H}$$

where, in a symmetric equilibrium,

$$\frac{\partial A}{\partial \alpha_H} = \left[(1-\ell)\left(\mu q_L + (1-\mu)q_H\right) - (1-\mu)q_H\right](a - c_o) = 2(1-\mu)A_H$$

with A_H the access revenues per heavy user. Intuitively, having an extra heavy user affects the access revenues in a double way. Suppose $A_H < 0$, then the

network not only pays more access contributions to its rival (for an amount of A_H), he foregoes also the access contributions (again for an amount of A_H) which he would have received if this heavy user had subscribed to his rival instead. Similarly, if $A_H > 0$, a heavy user is worth twice the access revenues he procures. In a symmetric equilibrium, these 'access' costs (benefits) are completely passed to the customer, who thus pays (is rewarded) twice for his contribution to the access deficit (revenues). As a result, equilibrium profits *including* access revenues on a customer equal $1/2\sigma$ *minus* the access revenues made on this customer.

$$\pi_H \equiv R_H + A_H = \frac{1}{2\sigma} - A_H$$

In the same way, profits per light user are $\pi_L = 1/2\sigma - A_L$. As in a symmetric equilibrium, $\mu A_L + (1-\mu)A_H = 0$, average per customer profits are equal to $1/2\sigma$.

Secondly, the calling pattern affects whether $\left\{\hat{q}_L, \hat{t}_L, \hat{q}_H, \hat{t}_H\right\}$ is incentive compatible, and which incentive constraint is binding in case it is not. Incentive conditions for $\left\{\hat{q}_L, \hat{t}_L, \hat{q}_H, \hat{t}_H\right\}$ can be rewritten as

$$\begin{aligned} u_L(\hat{q}_L) - u_L(\hat{q}_H) &\geq \hat{t}_L - \hat{t}_H \qquad (IC_L) \\ u_H(\hat{q}_L) - u_H(\hat{q}_H) &\leq \hat{t}_L - \hat{t}_H \qquad (IC_H) \end{aligned}$$

with IC_L and IC_H the incentive constraints of respectively the light and the heavy users. Compared to a balanced calling pattern, a *light biased calling pattern* decreases $\hat{t}_L - \hat{t}_H$ for $a > c_o$, as heavy (light) users pay (are rewarded) for their contribution to the access deficit (revenues). An access markup then has two opposite effects on incentive conditions. One due to the inflated marginal cost $c + (a - c_o)/2$, which is analyzed in Dessein (1999) and makes $\left\{\hat{q}_L, \hat{t}_L\right\}$ relatively less attractive compared to $\left\{\hat{q}_H, \hat{t}_H\right\}$, and another, due to the access premium heavy users pay and light users receive, which decreases $\hat{t}_L - \hat{t}_H$. For $\ell = \frac{1}{2}\left[\mu k_L/k + \mu\right]$, the two effects exactly cancel out and IC_L and IC_H are strictly satisfied for any access charge. With a slightly heavy biased calling pattern,[10] that is if $\ell < \frac{1}{2}\left[\mu k_L/k + \mu\right]$, IC_L will be violated for $\delta = k_H - k_L$ small. If, on the other hand, $\ell > \frac{1}{2}\left[\mu k_L/k + \mu\right]$, that is if the calling pattern is substantially light biased, IC_H will be violated for δ small. In each case, the IC violated by $\left\{\hat{q}_L, \hat{t}_L, \hat{q}_H, \hat{t}_H\right\}$, is binding in the implicit price discrimination equilibrium. In contrast with this, a *heavy biased calling pattern* increases $\hat{t}_L - \hat{t}_H$ for $a > c_o$ so that the access markup has an unambiguous effect on incentive conditions: it makes $\left\{\hat{q}_L, \hat{t}_L\right\}$ relatively less attractive compared to $\left\{\hat{q}_H, \hat{t}_H\right\}$ so that the IC of the light users is always binding for δ small. Appendix 8.2.1 gives a characterization of the equilibrium when an incentive constraint is binding.

[10] Remember that a calling pattern is light biased if and only if $\ell > \frac{\mu k_L}{k}$.

5.2 Differences in perceived substitutability

With linear pricing, we have shown how an endogeneous selection of customers affects the collusive power of the access charge when the calling pattern is unbalanced. As argued above, this endogeneous selection disappears with nonlinear pricing, since networks then use the fixed fee to compete for market share. The basic argument, however, still holds: whenever customers react differently to price-differentials between networks (including subscription fees), there is an endogeneous selection of customers and collusion may be possible.

Assume therefore that there are unbalanced flows between two customer groups with different substitutability parameters. Such different perceived substitutabilities can correspond to different brand loyalties, different search costs, a differentiated access to product information or publicity, different switching costs,... For simplicity, we will suppose that customers are homogeneous in volume demand ($k_L = k_H = 1$), but a fraction μ of *loyal* customers (subscript L), have a perceived substitutability of σ_L and receive a fraction ℓ of all calls, while the other customers are *disloyal* (subscript D) and have a substitutability $\sigma_D > \sigma_L$.

A network increases its average net outflow per customer by lowering its fixed fee, if loyal customers receive more calls than disloyal ones ($\ell > \mu$), since relatively more disloyal customers will then join him. Keeping usage fees constant, a higher access charge discourages thus a cut in the fixed fee and leads to softer competition. If on the other hand loyal customers call more than they are called, that is if $\ell < \mu$, an increase in the access charge toughens competition as it encourages a cut in the fixed fee, which then decreases the average net outflow per customer. The following proposition describes how this affect total profits:

Proposition 5 *If for equal usage fees, there are unbalanced flows between the two customer segments, the access charge is an instrument of collusion with nonlinear pricing; symmetric equilibrium profits are then given by*

$$\pi^* = \frac{1}{4\sigma} + \frac{\sigma_D - \sigma_L}{\sigma}(\ell - \mu)\, q(p^*)\frac{a - c_o}{2}$$

with $p^* = c + \frac{a-c_o}{2}$ *and* $\sigma \equiv \mu\sigma_L + (1-\mu)\sigma_D$. *If for equal usage fees, loyal customers receive more calls than disloyal customers, networks thus prefer an access charge above marginal cost; if disloyal customers receive more calls for equal marginal fees, they prefer an access charge below marginal cost.*

Proof. See appendix 8.2.2 ■

Note that profits increase with $q(p^*)\frac{a-c_o}{2} = q(p^* - c)q^*$, which, on its turn, increases with a if and only if $p^* < p^M = \frac{\eta c}{\eta - 1}$. Though networks prefer an access charge above marginal cost if loyal customers tend to receive more calls than they originate, they will thus never agree on an access charge a^* larger than a^M, where a^M is given by $p^M = c + \frac{a^M - c_o}{2}$.

6 Targeted entry

Customer heterogeneity gives scope to specialized networks. This is particularly relevant when analyzing entry as new telecommunication operators tend to target high volume markets such as businesses and big cities. Intuitively, the calling pattern will also matter here: all other things being equal, the attractiveness of a specific target segment is influenced considerably by the access charge when call-flows between segments are unbalanced. Whereas in the mature phase of competition, the major concern is the potential role of the access charge as a collusive device, one may thus wonder whether in the transition towards competition, an incumbent can impede entry on a specific customer segment by setting an appropriate access charge.

To address this question, we assume that there are two network operators, an incumbent (address $x = 0$, subscript I), with full coverage and an entrant (address $x = 1$, subscript E) which only covers ('targets') one customer segment. LRT have shown already that entry cannot be deterred as long as a) interconnection can be mandated, b) the incumbent is not allowed to charge a different price for calls terminating off-net and on-net, c) access charges are reciprocal. *As long as the calling pattern remains balanced*, heterogeneity in volume demand does not alter this result: given any access charge, by mimicking the price-structure of the incumbent (be it linear or not), the entrant can obtain half of the market-share in the overlap without incurring an access deficit. This is no longer true with *unbalanced calling patterns*, as the entrant then has a net out- or inflow of calls for equal prices. In other words, the *calling volume* does not matter but the *calling pattern* does. To focus on the effects of unbalancedness, we simplify our model therefore by assuming that customers only differ in incoming calls: all customers are of the same type $k = 1$, but the fraction of calls terminating on the target segment, ℓ_t, does not equal the fraction of customers belonging to this segment, μ_t (we denote by subscript t the "target" segment covered by the entrant).

6.1 Linear tariffs

Denoting by α_t the market share of the incumbent in the target segment, profits of the entrant and the incumbent are respectively:

$$\begin{aligned} \pi_E &= (1-\alpha_t)\mu_t \left(R(p_E) - f\right) + A_E \\ \pi_I &= \left[\alpha_t\mu_t + 1 - \mu_t\right] \left(R(p_I) - f\right) + A_I, \end{aligned}$$

where

$$\begin{aligned} \alpha_t &= \frac{1}{2} + \sigma\left[v(p_I) - v(p_E)\right] \\ A_E &= -A_I = (1-\alpha_t)\left[\ell_t(\alpha_t\mu_t + (1-\mu_t))\, q_I - (\alpha_t\ell_t + 1 - \ell_t)\mu_t q_E\right](a - c_o). \end{aligned}$$

Define b as the ratio of incoming to outgoing calls for equal prices in the target segment:

$$b \equiv \frac{\ell_t}{\mu_t}$$

Then $b < 1$ if and only if the target segment has a net outflow of calls for equal prices. Define p_σ as the lowest price for which the entrant prices himself out of the market if the incumbent charges the monopoly price p^M (hence $p_\sigma > p^M$) : $v(p_\sigma) = v(p^M) - 1/2\sigma$.
Given $p_I = p^M$ and $p_E = p_\sigma$, the entrant's potential customers still call more than they are called if and only if

$$\mu_t q(p_\sigma) \geq \ell_t q(p^M) \Longleftrightarrow \left[1 - b^{\frac{\eta-1}{\eta}}\right] v(p^M) \geq 1/2\sigma \tag{15}$$

The next proposition shows that if the target segment has a net outflow of calls ($b < 1$), then for a sufficiently large, the incumbent can act as a monopolist if networks are good substitutes (σ high), unbalancedness is high (b small) or fixed costs per customer are important:

Proposition 6

- *If* $\left[1 - b^{\frac{\eta-1}{\eta}}\right] v(p^M) \geq 1/2\sigma$, *then for a large enough access charge, a cornered market equilibrium exists in which the incumbent enjoys monopoly profits.*
- *If* $0 < \left[1 - b^{\frac{\eta-1}{\eta}}\right] v(p^M) < 1/2\sigma$, *then* $\exists \hat{f} \in \left]0, (p^M - c)q(p^M)\right[$ *such that*
  1. *For* $\hat{f} \leq f \leq R^M$: $\exists\ a', a''$ *with* $c_o \leq a' < a''$ *such that the same equilibrium exists for any access charge* $a \in \left]a', a''\right[$
  2. *For* $f < \hat{f}$, *no cornered market equilibrium exists in which the incumbent enjoys monopoly profits.*

Proof. See Appendix 8.3.1 ■
Besides the amount of unbalancedness, whether or not entry can be impeded (while keeping monopoly profits) thus depends essentially on the substitutability. The more customers perceive the entrant's services as different from those of the incumbent, the harder it is to keep the entrant out of the market. E.g. entry by 'niche players' with very differentiated products is hard to impede as even for large price differentials, some customers prefer the entrant's products. Even if the entrant is able to get rid of the access deficit by charging a high price without losing all his clients (and thus (15) is not satisfied), an appropriate access charge may still push him out of the market if fixed costs are high enough. Denote by p_f the highest price for which an operator breaks even:

$$(p_f - c)\, q(p_f) = f; \quad p_f \geq p^M.$$

When f is high enough, p_f comes arbitrarily close to the monopoly price and an access charge just above c_o pushes the entrant out of the market. For p_f substantially larger than p^M, however, one needs a large enough access charge $a > a' > c_o$ to ensure that the access deficit is always more important than the retail revenues which the entrant can make by setting a price $p_E < p_f$. On the other hand, there is also a maximal access charge a'' above which the entrant can obtain a positive profit by setting p_E high enough: denoting by $p_b < p_\sigma$ the usage fee which rebalances in and outflow between entrant and incumbent ($\mu_t q(p_b) = \ell_t q(p^M)$), for a high enough, the entrant can make access revenues which cover his retail losses by charging $p_E \in]p_b, p_\sigma[$. A decrease in f increases the entrant's profits and consequently lowers a'' and raises a' (entry is harder to impede). While for p_f close to p^M and thus f large, we definitely have $a'' > a' > c_o$,[11] there exists a critical value $\hat{f}$ below which $a'' < a'$ and entry is always profitable. Intuitively, for f small enough, $p_b < p_f$ so that, if $a \geq c_o$, the entrant always makes both positive retail profits and access revenues by charging $p_E \in]p_b, p_f[$.

One could derive a similar result for entry on a segment with customers receiving more calls than they originate ($\ell_t > \mu_t$). For large enough an unbalancedness and/or high enough a fixed cost, the only way for the latter to prevent his customers from calling *less* than they are being called is to set a price below the Ramsey price (the lowest price for which $(p-c)q(p) = f$). With a similar reasoning as above, but now for access charges below marginal cost, entry may then be impeded. This result, however, is of more limited interest as it would often require negative access charges, in which case each network could install a machine calling constantly the other network.

We conclude that if the incumbent operator has considerable power in the setting of the access charge, the calling pattern may affect considerably the attractiveness of customer segments and thus the target decision. High volume segments, e.g., are often very profitable with respect to the retail revenues they provide, but to the extent that they yield a net outflow of calls, targeting them might not always be a good choice.

6.2 Nonlinear tariffs

As we assumed customers to be homogeneous in their volume demand, networks can never do better than offering a two-part tariff of the form, $t_i(q) = F_i + p_i q$, $i = I, E$. Define

$$\pi_C \equiv \delta v(c) - 1/2\sigma,$$

where

$$\delta \equiv 1 - \eta b^{\frac{\eta-1}{\eta}} + (\eta - 1)b$$

[11] In the limit case $f = (p^M - c)q(p^M)$, $p_f = p^M < p_b$ so that $a' = c_o$ and $a'' > c_o$.

is strictly positive if and only if $b \equiv \ell_t/\mu_t \neq 1$, that is if and only if the calling pattern is unbalanced.[12]

Proposition 7 *If $\pi_C < 0$, no cornered market equilibrium exists. If $\pi_C \geq 0$, then cornered market equilibria may exist, in which case profits of the incumbent are given by π_C.*

Proof. See appendix 8.3.2 ■

Condition $\pi_C \geq 0$ stems from the fact that the incumbent's profits must be nonnegative. It is thus a *necessary* but far from sufficient condition: as long as π_C is close to 0, the incumbent would probably prefer to cream the captive segment and share the other segment with the entrant. This is in sharp contrast with our result under linear pricing where (15) is a *sufficient* condition for the existence of a cornered market equilibrium in which the incumbent obtains *monopoly profits.* Intuitively, it is tougher to push the entrant out of the market when the latter is not restricted to linear prices. The incumbent, for example, can never push the entrant out of the market by insisting on a very high access charge. The entrant would then easily make (large) profits by charging a fixed fee low enough to get a positive market share, while setting the usage fee high enough as to make huge access revenues which are more than sufficient to compensate for the low fixed fee. Proposition 7 shows that, while an "intermediate" access charge may put the entrant at some disadvantage vis à vis the incumbent, in order to avoid entry, the incumbent is forced to keep profits low.

Notice that the conditions $\pi_C < 0$ and (15) are very similar: whereas the latter states that entry deterrence is possible with linear prices if unbalancedness is sufficiently large or networks are close enough substitutes, the former says that entry deterrence is impossible under nonlinear pricing if unbalancedness is not large enough or networks are too much differentiated. We now argue that entry is in general harder to impede under nonlinear pricing than under linear pricing. To make our comparison, we suppose that the incumbent can freely determine the access charge.

- First of all, if σ is very high, the incumbent can both make monopoly profits and impede entry under linear pricing. In contrast, even if $\sigma = \infty$, profits in a cornered market equilibrium are bounded by $\delta v(c)$ under nonlinear pricing. While the incumbent might then be able to impede entry by setting an appropriate access charge, he could prefer to accommodate entry and cream the captive segment. Indeed, by fixing an access charge $a = c_o$ and creaming the captive market segment, the incumbent obtains a profit equal to at least

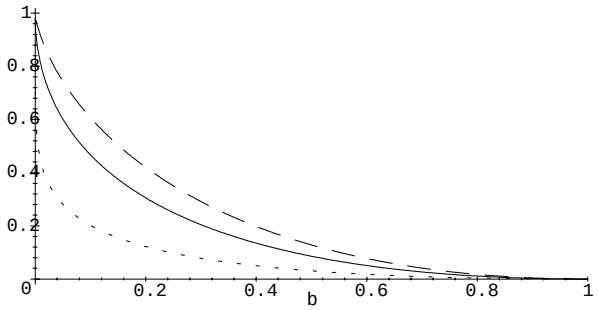
$$(1-\mu_t)\pi^M = (1-\mu_t)\left(v_o - f + v(c) - 1/2\sigma\right)$$

[12] For $b < 1$ ($b > 1$), δ is decreasing (increasing) in b.

If we assume that the fixed surplus v_o of being able to make (and receive) telephone calls, is larger than the fixed cost f, a sufficient condition for entry accommodation is then[13]

$$1 - \mu_t > \delta \tag{16}$$

Intuitively, the larger the captive market $(1 - \mu_t)$, the larger the temptation to accommodate entry. The next graph shows how δ varies with b for price elasticities of respectively $\eta = 1.2$ (dotted line, below), $\eta = 2$ (solid line) and $\eta = 5$ (dashed line, above). The horizontal axis goes from $b = 0$ (target customers receive no calls at all) to $b = 1$ (balanced calling pattern).



δ as a function of ratio inflow/outflow[15]

One can see that δ is relatively small as long as $b \geq 0.5$ (target customers call not more than twice as much as they are being called for equal prices) and this all the more so that η is small. If e.g. $\eta = 2$, and $b \geq 0.5$, then entry is accommodated whenever at least 9% of the market is captive.[16]

- Secondly, even if v_o is considerably smaller than f and the target segment (μ_t) is very large, it will in general require a higher substitutability for entry deterrence to occur under nonlinear pricing. Under linear pricing, a *sufficient* condition for the existence of a cornered market equilibrium in which the incumbent enjoys monopoly profits is that

$$(1 - b^{\frac{\eta-1}{\eta}})kv(p^M) > 1/2\sigma \Leftrightarrow \tfrac{\eta-1}{\eta}(1 - b^{\frac{\eta-1}{\eta}})kv(c) > 1/2\sigma \tag{17}$$

Under nonlinear pricing, a necessary condition for the existence of a cornered market equilibrium is that $\pi_C \geq 0$. For $\mu_t > 2/5$ and $a = c_o$, however, one can show that there exists a unique shared market equilibrium in which the incumbent's total profit is decreasing in μ_t and bounded below by the symmetric equi-

[13] Assuming $\sigma = \infty$. For smaller values of σ, the temptation to cream the captive market is even larger as (16) then becomes $1 - \mu_t > \delta - \mu_t/2\sigma$

[15] for equal prices, in the target segment

[16] Indeed, in the latter case δ is given by $\left(1 - \sqrt{0.5}\right)^2 = 0.086$.

librium profits $1/4\sigma$.[17] If the incumbent can freely determine the access charge, a *necessary* condition for the existence of a cornered market equilibrium is thus $\pi_C \geq 1/4\sigma$ or

$$\frac{2}{3}\left[1 - \eta b^{\frac{\eta-1}{\eta}} + (\eta - 1)b\right] kv(c) > 1/2\sigma \tag{18}$$

It follows that for $\eta \geq 3$, it is always harder (in the sense of requiring a higher substitutability) to impede entry under nonlinear pricing. Indeed:

$$(1 - b^{\frac{\eta-1}{\eta}}) - (1 - \eta b^{\frac{\eta-1}{\eta}} + (\eta - 1)b) = (\eta - 1)(b^{\frac{\eta-1}{\eta}} - b) > 0$$

Similarly, for $\eta < 3$ and when b is close to 1 (unbalancedness is not too large), the LHS of (17) is larger than the LHS of (18) and entry deterrence is easier under linear prices. Only for b close to 0 (unbalancedness is large) and $\eta < 3$, we cannot conclude as then a *sufficient* condition (for the existence of a cornered market equilibrium *with monopoly profits*) is harder to satisfy than a *necessary* condition (for the existence of *any* cornered market equilibrium).

7 Conclusion

The main interest in analyzing the impact of heterogeneous calling patterns on network competition is two-fold:
- Customer heterogeneity is likely to lead to unbalanced flows between customers of different types. The access charge then alters the attractiveness of customers which tend to have a deficit or a surplus on their 'call balance'. We have shown that under linear pricing, this affects substantially the pricing decisions of networks and yields a new (collusive) role for the access charge. If the unbalancedness is not negligible, its impact on prices is even more important than that of the raise-each-other's cost effect, highlighted by the literature, if price changes only have a small impact on volume demand per customer (elasticity is low), but its effect on the customer's choice from which network to purchase these services is large (substitutability is high); two demand features which are confirmed by current empirical studies.[18] If networks compete in nonlinear prices, the unbalancedness effect only holds if customers of different types perceive the substitutability of networks in a different way. Unbalanced calling patterns, however, always have a large impact on the way how networks compete for customers of different types and how they discriminate them implicitly using a menu of tariffs.
- Second, if entry occurs not randomly but on high volume segments such as

[17] The first order conditions then yield $p_E = p_I = c$, $F_I = \frac{1 - \mu_t(1 - \alpha_t)}{\mu_t \sigma} + f$ and $F_E = \frac{\mu_t(1 - \alpha_t)}{\mu_t \sigma} + f$, from which $\alpha_t = 5/6 - 1/3\mu_t$ and $\pi_I = \frac{(2/3 - \mu_t/6)^2}{\mu_t \sigma} \geq 1/4\sigma$.

[18] See, for example, Taylor (1994).

cities or business areas which generate a net outflow of calls, one may fear that in a deregulated environment, the incumbent may insist on a high access charge in order to impede entry. While under linear pricing, this intuition turns out to be right, it must be qualified if there is competition in nonlinear pricing. High access charges are then not so effective in deterring entry, as the entrant can collect huge access revenues by setting a higher usage fee than the incumbent, while keeping a significant market share by charging a lower fixed fee. In contrast with linear pricing, where monopoly profits may be enjoyed, entry can only be impeded if profits are sufficiently low, in which case the incumbent often prefers to accommodate entry.

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8 Appendix

8.1 Heterogeneity in demand and unbalanced calling patterns

Proof of proposition 2:
The symmetric equilibrium price p^* must satisfy the first order condition:

$$\begin{aligned}\frac{\partial \pi_i}{\partial p_i}_{|p_1=p_2=p^*} &= \frac{k}{2}\left[R'(p^*) - \tfrac{a-c_o}{2}q'(p^*)\right] - \sigma k q(p^*)\left[k(1+h)R(p^*) - f\right] \\ &= \frac{k}{2}\frac{q^*}{p^*}\left[(\eta-1)(p^M - p^*) + \eta\tfrac{a-c_o}{2} - 2\sigma p^*\hat{\pi}(p^*)\right] = 0\end{aligned}$$

with $\hat{\pi}(p) = k(1+h)R(p) - f$. Using the implicit function theorem we obtain

$$\frac{\partial p^*}{\partial k} = \frac{-2\sigma(1+h)p^*R(p^*)}{\eta - 1 + 2\sigma\left[\hat{\pi}(p^*) + p^*\hat{\pi}'(p^*)\right]}$$

With exactly the same argument as LRT,[19] it is shown that the denominator is positive. It follows that $\partial p^*/\partial k$ is negative. By the same argument, also $\partial p^*/\partial h$ is negative. ■

Proof of proposition 3:
The symmetric equilibrium price p^* must satisfy the first order condition,

$$\frac{k}{2}\left[R'(p^*) - \tfrac{a-c_o}{2}q'(p^*)\right] - \sigma k^2 q(p^*)\left[(1+h)R(p^*) - f/k\right] - \psi(a-c_o)\sigma k q(p^*)^2 =$$

$$\frac{k}{2}\frac{q^*}{p^*}\left[(\eta-1)(p^M - p^*) + (\eta - 4\sigma k p^* q^* \psi)\frac{a-c_o}{2} - 2\sigma p^* \hat{\pi}(p^*)\right] = 0,$$

and thus

$$\frac{\partial p^*}{\partial a} = \frac{\frac{\eta}{2} - 2\psi k p^* q(p^*)\sigma}{\eta - 1 + 2\sigma\left[\hat{\pi}(p^*) + p^*\hat{\pi}'(p^*) - \psi q^*(\eta-1)(a-c_o)\right]}$$

As for $a = c_o$, p^* is independent of ψ and the denominator is positive, it follows that $\dfrac{\partial^2 p^*}{\partial a \partial \psi} < 0$. By continuity, this also holds for a close to c_o. To conclude the proof, we thus only have to show that if $\psi > 0$ (heavy biased calling pattern), p^* decreases with a if and only if $4\sigma\psi k\tilde{p}q(\tilde{p}) > \eta$ where $\tilde{p}$ denotes the equilibrium price in case $a = c_o$. For a close to c_o, the denominator of $\partial p^*/\partial a$ is positive and we denote by A the largest access charge below which this denominator is still strictly positive. We show that if for $a = c_o$, $4\psi k\tilde{p}q(\tilde{p})\sigma > \eta$ and thus $\partial p^*/\partial a < 0$, then $\partial p^*/\partial a < 0$ for any access charge smaller than A. Indeed suppose that there exists an access charge $a' < A$ for which $\partial p^*/\partial a > 0$ and thus $4\psi k p^* q(p^*)\sigma < \eta$, then by continuity, there exists an access charge $a'' < a'$ for which $4\psi k p^* q(p^*)\sigma = \eta$. Consequently, at a'', all the derivatives of p^* with respect to a are zero so that $\dfrac{\partial p^*}{\partial a} = \dfrac{\partial p^*}{\partial a}_{|a=a''} = 0$ for any access charge smaller than A. As a result also $4\psi k\tilde{p}q(\tilde{p})\sigma = \eta$, a contradiction. By the same argument, if $4\psi k\tilde{p}q(\tilde{p})\sigma < \eta$ then for any access charge smaller than A, $4\psi k p^* q(p^*)\sigma < \eta$ and p^* increases with a. ■

8.2 Nonlinear tariffs

8.2.1 Standard model

Proof of proposition 4:
We only proof part (ii), the proof of (i) is identical to the one given in Dessein (1999) for the case of a balanced calling pattern.

1) Equilibrium if networks can discriminate explicitly

[19] Laffont, Rey, Tirole 1998a; appendix A, p31, uniqueness and monotonicity of p^* with respect to a, just substitute $\pi(p)$ by $\hat{\pi}(p)$ and use $\pi(p) > 0 \Rightarrow \hat{\pi}(p) > 0$.

Since market shares only depend on the variable net surplus, it is convenient to view competition as one in which networks pick quantities (q_H, q_L) and net surpluses (w_H, w_L) rather than quantities and tariffs (t_H, t_L). Profits are then

$$\begin{aligned}\pi &= \mu\alpha_L\left[\tfrac{\eta}{\eta-1}k_L^{1/\eta}q_L^{1-1/\eta} - w_L - cq_L - f\right] \\ &\quad +(1-\mu)\alpha_H\left[\tfrac{\eta}{\eta-1}k_H^{1/\eta}q_H^{1-1/\eta} - w_H - cq_H - f\right] \\ &\quad -\left[\mu\alpha_L q_L + (1-\mu)\alpha_H q_H\right]\left[\ell(1-\alpha_L) + (1-\ell)(1-\alpha_H)\right](a-c_o) \\ &\quad +\left[\mu(1-\alpha_L)q'_L + (1-\mu)(1-\alpha_L)q'_H\right]\left[\ell\alpha_L + (1-\ell)\alpha_H\right](a-c_o)\end{aligned}$$

We are looking for a symmetric equilibrium. For $a = c_o$, network i' s profits on the customer segment s are strictly concave in $\{q_s, w_s\}$[20]. As a result, total profits given k_L, k_H are strictly concave in $\{q_L, w_L, q_H, w_H\}$ for $a = c_o$ and the Hessian matrix $D^2\pi(q_L, w_L, q_H, w_H)$ is negative semidefinite for $a = c_o$. Fix the average customer type k. As all terms of $D^2\pi(q_L, w_L, q_H, w_H)$ are continuous in k_L, k_H, ℓ and a, then for any $\delta_o = k_H - k_L$, one can find an access charge $a_o > c_o$ such that $D^2\pi(q_L, w_L, q_H, w_H)$ is still negative semidefinite and thus profits are strictly concave, for $c_o \leq a \leq a_o$, $0 \leq k_H - k_L \leq \delta_o$ and $\ell \in [0,1]$. A candidate equilibrium satisfying the FOC is then effectively an equilibrium. From the FOC with respect to q_L and q_H, equilibrium marginal fees are equal to perceived marginal costs, $\hat{p} = c + \frac{a-c_o}{2}$, leading to equilibrium quantities $\hat{q}_s = k_s q(c + \frac{a-c_o}{2})$, $(s = L, H)$. From the FOC with respect to w_L and w_H, equilibrium tariffs are given by

$$\begin{aligned}\hat{t}_L &= 1/2\sigma + f + c\hat{q}_L + \frac{\mu\hat{q}_L - \ell\left[\mu\hat{q}_L + (1-\mu)\hat{q}_H\right]}{\mu}(a-c_o) &(19)\\ &= 1/2\sigma + f + c\hat{q}_L - 2A_L &(20)\\ \hat{t}_H &= 1/2\sigma + f + c\hat{q}_H - \frac{\mu\hat{q}_L - \ell\left[\mu\hat{q}_L + (1-\mu)\hat{q}_H\right]}{1-\mu}(a-c_o) \\ &= 1/2\sigma + f + c\hat{q}_L - 2A_H &(21)\end{aligned}$$

with A_L and A_H the access revenues respectively per light and per heavy user. It follows that profits per light user, respectively heavy user, are given by

$$\begin{aligned}\hat{\pi}_L &= \hat{t}_L + A_L - f - c\hat{q}_L = 1/2\sigma - A_L &(22)\\ \hat{\pi}_H &= \hat{t}_H + A_H - f - c\hat{q}_H = 1/2\sigma - A_H &(23)\end{aligned}$$

2) Equilibrium if network cannot discriminate explicitly.

Substituting the equilibrium under explicit price discrimination $\{\hat{q}_L, \hat{w}_L, \hat{q}_H, \hat{w}_H\}$ in the incentive constraints (13) and (14), we find after some manipulations that, in order for the latter to be satisfied by $\{\hat{q}_L, \hat{w}_L, \hat{q}_H, \hat{w}_H\}$, one must have

$$\left[1 + 2\frac{\mu k_L - \ell k}{\mu(1-\mu)\Delta k}\right]\left[\frac{\frac{a-c_o}{2}}{c + \frac{a-c_o}{2}}\right] \geq 1 - \frac{\eta}{\eta-1}k_H^{1/\eta}\frac{\left[k_H^{1-1/\eta} - k_L^{1-1/\eta}\right]}{\Delta k} \quad (24)$$

[20] See Laffont-Rey-Tirole 1998a, appendix B.

$$\left[1+2\frac{\mu k_L-\ell k}{\mu(1-\mu)\Delta k}\right]\left[\frac{\frac{a-c_o}{2}}{c+\frac{a-c_o}{2}}\right] \leq 1-\frac{\eta}{\eta-1}k_L^{1/\eta}\frac{\left[k_H^{1-1/\eta}-k_L^{1-1/\eta}\right]}{\Delta k} \quad (25)$$

One can verify that the RHS of (24) is strictly negative and the RHS of (25) is strictly positive as long as $k_L < k_H$. Denoting $\delta = k_H - k_L$, it follows that given any $\delta > 0$, for a close enough to c_o, both $IC's$ are satisfied and $\{\hat{q}_L, \hat{w}_L, \hat{q}_H, \hat{w}_H\}$ is also the equilibrium under implicit price discrimination.
Fix now k and $a > c_o$. As long as

$$1+2\frac{\mu k_L-\ell k}{\mu(1-\mu)\Delta k} > 0 \Leftrightarrow \ell < \frac{1}{2}\left[\frac{\mu k_L}{k}+\mu\right] \quad (26)$$

that is, with a heavy biased, balanced or slightly light biased calling pattern, (24), the incentive constraint of the heavy users will be satisfied for any $a > c_o$. On the other hand, given $a > c_o$, for $\delta = k_H - k_L$ small enough, the IC of the light users will be violated by $\{\hat{q}_L, \hat{w}_L, \hat{q}_H, \hat{w}_H\}$. Indeed, writing k_H and k_L respectively as $k_H = k + \mu\delta$ and $k_L = k - (1-\mu)\delta$ (and thus also seeing ℓ as a function of $\delta : \ell \equiv \ell(\delta, k, \mu)$ with $\ell(0, k, \mu) = \mu$), one can verify that the RHS of both (25) and (24) tend to zero when δ goes to zero, while the limit of the LHS stays then strictly positive. If on the other hand $\ell > \frac{1}{2}\left[\frac{\mu k_L}{k}+\mu\right]$, that is, if heavy users call considerably more than they are being called, given $a > c_o$, the IC of the heavy users will be violated when δ goes to zero. From the following lemma, the IC violated by $\{\hat{q}_L, \hat{w}_L, \hat{q}_H, \hat{w}_H\}$ is binding in a symmetric equilibrium under implicit price discrimination:

Lemma 2 *If the explicit price discrimination equilibrium, $\{\hat{q}_L, \hat{t}_L, \hat{q}_H, \hat{t}_H\}$ violates the incentive constraint of the light (heavy) users, then for $\delta = k_H - k_L$ small, a symmetric equilibrium $\{t_L^*, q_L^*, t_H^*, q_H^*\}$ under implicit price discrimination is such that the incentive constraint of the light (heavy) users is binding.*

Proof. The proof is a straightforward extension of the proof of the same lemma in Dessein (1999) which only holds for a balanced calling pattern. ■

Finally, for $\ell = \frac{1}{2}\left[\frac{\mu k_L}{k}+\mu\right]$,the IC of both heavy and light users are always satisfied and for any access charge, if a symmetric equilibrium exists, it is given by $\{\hat{q}_L, \hat{w}_L, \hat{q}_H, \hat{w}_H\}$.
We characterize now the equilibrium in case an incentive constraint is binding. The FOC with respect to q_L and q_H yield

$$\begin{aligned}\mu\alpha_L\left[k_L^{1/\eta}q_L^{-1/\eta}-(c+(a-c_o)/2)\right]-\lambda_H k_H^{1/\eta}-k_L^{1/\eta}q_L^{-1/\eta} &= 0\\ (1-\mu)\alpha_H\left[k_H^{1/\eta}q_H^{-1/\eta}-(c+(a-c_o)/2)\right]+\lambda_L\left[k_H^{1/\eta}-k_L^{1/\eta}\right]q_H^{-1/\eta} &= 0\end{aligned}$$

If $\lambda_L > 0$, it follows that:

$$q_L^* = \hat{q}_L \quad \text{and} \quad q_H^* = k_H q \left(c + \tfrac{a-c_o}{2}\right) \left(1 + \frac{2\lambda_L}{(1-\mu)} \frac{\left[k_H^{1/\eta} - k_L^{1/\eta}\right]}{k_H^{1/\eta}}\right)^{\eta} > \hat{q}_H$$

If on the other hand $\lambda_H > 0$, we find

$$q_H^* = \hat{q}_H \quad \text{and} \quad q_L^* = k_L q \left(c + \tfrac{a-c_o}{2}\right) \left(1 - \frac{2\lambda_H}{\mu} \frac{\left[k_H^{1/\eta} - k_L^{1/\eta}\right]}{k_L^{1/\eta}}\right)^{\eta} < \hat{q}_L$$

From the FOC with respect to w_L and w_H, if $\lambda_L > 0$, profits per heavy user, π_H^*, and light user, π_L^*, are:

$$\pi_H^* = \hat{\pi}_H + \frac{\lambda_L}{\sigma(1-\mu)} \quad \text{and} \quad \pi_L^* = \hat{\pi}_L - \frac{\lambda_L}{\sigma(\mu)}$$

while if $\lambda_H > 0$, we have

$$\pi_H^* = \hat{\pi}_H - \frac{\lambda_H}{\sigma(1-\mu)} \quad \text{and} \quad \pi_L^* = \hat{\pi}_L + \frac{\lambda_H}{\sigma(\mu)}$$

8.2.2 Differences in perceived substitutability

Proof of proposition 5:
As customers are homogeneous in volume demand, networks can never do better than offering a two-part tariff of the form, $t_i(q) = F_i + p_i q$, $i = 1, 2$. Market shares, however, depend only on the offered net surpluses $w_i = v(p_i) - F_i$; it is therefore useful to see network competition as one in which networks compete in net surpluses and usage fees rather than fixed fees and usage fees. Market shares of network 1 in respectively the loyal and the disloyal segment are then respectively

$$\alpha_L = \frac{1}{2} + \sigma_L \left[w_1 - w_2\right] \quad \text{and} \quad \alpha_D = \frac{1}{2} + \sigma_D \left[w_1 - w_2\right]$$

Profits of network 1 are given by

$$\begin{aligned} \pi_1 &= \alpha \left[v(p_1) + (p_1 - c)q(p_1) - w_1 - f\right] \\ &\quad + \left(\hat{\alpha}(1-\alpha)q(p_2) - \alpha(1-\hat{\alpha})q(p_1)\right)(a - c_o) \end{aligned}$$

where

$$\alpha = \mu\alpha_L + (1-\mu)\alpha_D \quad \text{and} \quad \hat{\alpha} = \ell\alpha_L + (1-\ell)\alpha_D$$

which, if $\alpha_s \in]0, 1[$, $(s = L, D)$, can be rewritten as

$$\begin{aligned} \alpha &= \frac{1}{2} + \left(\mu\sigma_L + (1-\mu)\sigma_D\right)\left[w_1 - w_2\right] \equiv \frac{1}{2} + \sigma\left[w_1 - w_2\right] \\ \hat{\alpha} &= \frac{1}{2} + \left(\ell\sigma_L + (1-\ell)\sigma_D\right)\left[w_1 - w_2\right] \end{aligned}$$

As usual, the first order condition with respect to p_i yields

$$p_1 = c + (1 - \hat{\alpha})(a - c_o)$$

and thus in a symmetric equilibrium: $p^* = c + \frac{a-c_o}{2}$. The first order condition with respect to w_i in a symmetric equilibrium yields:

$$0 = -\frac{1}{2} + \sigma \left[v(p^*) + (p^* - c)q(p^*) - w^* - f \right] + (a - c_o)q(p^*) \left(\ell\sigma_L + (1 - \ell)\sigma_D - \sigma \right))$$

The term between square brackets is exactly the total industry profit, per firm profits equal thus

$$\begin{aligned} \pi(p^*, w^*) &= \frac{1}{4\sigma} + (\ell - \mu) * \frac{\sigma_D - \sigma_L}{\sigma} * \frac{a - c_o}{2} * q(p^*) \\ &= \frac{1}{4\sigma} + (\ell - \mu) * \frac{\sigma_D - \sigma_L}{\sigma} * (p^* - c)q(p^*). \end{aligned}$$

As a result, with a loyal biased calling pattern ($\ell > \mu$), profits increase with a for $p^* \leq p^M = \dfrac{\eta c}{\eta - 1}$, that is for $\frac{a-c_o}{2} \leq \frac{c}{\eta - 1}$. If, on the other hand, $\ell < \mu$, profits decrease with a as long as a symmetric equilibrium exists (and $p^* \leq p^M$). As usual, it is easy to prove that an equilibrium always exists for a close to c_o.

8.3 Targeted entry

8.3.1 Linear tariffs

Proof of proposition 6:
The profit function of the entrant can be rewritten as

$$\begin{aligned} \pi_E &= (1 - \alpha_t)\mu_t \left(kR(p_E) - f \right) + \\ &\quad (1 - \alpha_t)\mu_t k\ell_t \left[\left(\alpha_t + \frac{1 - \mu_t}{\mu_t} \right) q_M - \left(\alpha_t + \frac{1 - \ell_t}{\ell_t} \right) q_E \right] (a - c_o) \end{aligned}$$

For $p_E < p_M - \varepsilon,\ q_E > q_M + \delta$ and the term between square brackets is always negative and bounded away from zero if $\mu_t > \ell_t$. Under condition (15), this is always the case. For $p_E \geq p_M - \varepsilon$ with ε small enough, the term between square brackets is increasing in p_E. Indeed, deriving with respect to p_E yields

$$\sigma q_E(q_M - q_E) - q'_E \left(\alpha_t + \frac{1 - \ell_t}{\ell_t} \right)$$

This term is thus negative and bounded away from zero if it is for $p_\sigma = \min_p \{p; \alpha_t(p_M, p) = 1\}$, this is when

$$\mu_t q(p_\sigma) \geq \ell_t q(p^M) \tag{27}$$

The entrant then makes losses for high enough an access charge. p_σ is given by

$$\frac{1}{2} = \frac{k\sigma}{\eta - 1}\left[\frac{1}{p_M^{\eta-1}} - \frac{1}{p_\sigma^{\eta-1}}\right]$$

so that

$$\frac{p_M^{\eta-1}}{p_\sigma^{\eta-1}} = \frac{2k\sigma}{(\eta-1)p_\sigma^{\eta-1} + 2k\sigma}$$

Condition (27) can thus be rewritten as

$$\frac{q(p_\sigma)}{q(p_M)} = \left[\frac{2k\sigma}{(\eta-1)p_\sigma^{\eta-1} + 2k\sigma}\right]^{\frac{\eta}{\eta-1}} \geq b$$

$$\Leftrightarrow \frac{(\eta-1)p_\sigma^{\eta-1}}{2k\sigma} \leq b^{-\frac{\eta-1}{\eta}} - 1 \Leftrightarrow \frac{1}{2k\sigma v(p_\sigma)} \leq b^{-\frac{\eta-1}{\eta}} - 1$$

$$\Leftrightarrow \frac{1}{2k\sigma v(p_I) - 1} \leq b^{-\frac{\eta-1}{\eta}} - 1 \Leftrightarrow \left[1 - b^{\frac{\eta-1}{\eta}}\right] kv(p_I) \geq \frac{1}{2\sigma}$$

The proof of the second part of proposition *6* is given in the text.

8.3.2 Nonlinear tariffs

Proof of proposition 7:
Consider a *candidate cornered market equilibrium* $\{p_I, F_I, p_E, F_E\}$ in which p_i and F_i are respectively the usage fee and the fixed fee charged by network i. We denote by w_I and w_E, the resulting net surpluses for a customer with address $x = 1$:

$$w_I = v(p_I) - F_I - 1/2\sigma \quad \text{and} \quad w_E = v(p_E) - F_E$$

Given $\{p_I, F_I\}$, the entrant may not be able to make nonnegative profits. The following lemma shows gives us sufficient conditions for this to be verified:

Lemma 3 *If* $(p_I - c)(a - c_o) \leq (1 - \ell_t)(a - c_o)^2$, *no entry is possible if and only if the entrant cannot obtain nonnegative profits by having an infinitely small market share.*

Proof. It is obvious that if the entrant can obtain nonnegative profits by having an infinitely small market share, no cornered market equilibrium exists. We thus only have to prove the "*if*" part. In this proof, it is useful to see network competition as one in which networks pick usage fees and net surpluses rather than usage fees and fixed fees, as net surpluses determine directly the market shares. Given a strategy $(p_I, w_I)$of the incumbent, it is always optimal for the entrant to set its usage fee at perceived marginal cost:

$$p_E^* = p_E(w_E) \equiv c + (1 - \alpha_t(w_I, w_E)\ell_t)(a - c_o)$$

where $\alpha_t(w_I, w_E)$ is the market share of the incumbent in the overlap. In what follows, we denote by $\hat{\pi}_E(w_E)$, the entrant's maximal profits given (p_I, w_I, w_E) :

$$\begin{aligned}\hat{\pi}_E(w_E) &\equiv \pi_E(w_I, p_I, w_E, p_E^* = p_E(w_E)) \\ &= \mu_t(1-\alpha_t(w_I,w_E))\left[(p_E^*-c)kq(p_E^*)+kv(p_E^*)-w_E-f\right]+ \\ &\quad (1-\alpha_t(w_I,w_E))\alpha_t(w_I,w_E)\ell_t\mu_t k\left[q(p_I)-q(p_E^*)\right](a-c_o)+ \\ &\quad (1-\alpha_t(w_I,w_E))k\left[\ell_t(1-\mu_t)q(p_I)-\mu_t q(p_E^*)(1-\ell_t)\right](a-c_o)\end{aligned}$$

We prove now that if $\hat{\pi}_E(\bar{w}) < 0$, with $\alpha_t(w_I, \bar{w}) = 1-\varepsilon$, ($\varepsilon$ infinitely small), then there exists no $\tilde{w}_E > \bar{w}$ such that $\hat{\pi}_E(\tilde{w}_E) \geq 0$. One has

$$\begin{aligned}\frac{d\hat{\pi}_E(w_E)}{dw_E} &= \sigma\left[\frac{\hat{\pi}_E(w_E)}{(1-\alpha_t(w_I,w_E))}-(1-\alpha_t(w_I,w_E))\mu_t\ell_t k\left[q(p_I)-q(p_E^*)\right](a-c_o)\right] \\ &\quad -\mu_t(1-\alpha_t(w_I,w_E))\end{aligned}$$

as $\dfrac{d\hat{\pi}_E(w_E)}{dp_E^*} = 0$. Suppose now that indeed, $\exists\tilde{w}_E > \bar{w} : \hat{\pi}_E(\tilde{w}_E) \geq 0$, then, by continuity $\exists\breve{w}_E \in [\bar{w}, \tilde{w}_E[\,, \hat{\pi}_E(\breve{w}_E) < 0 : \dfrac{d\hat{\pi}_E(w_E)}{dw_E} \mid w_E = \breve{w}_E > 0$. However, from $\hat{\pi}_E(\breve{w}_E) < 0$ follows that $\dfrac{d\hat{\pi}_E(w_E)}{dw_E} \mid w_E = \breve{w}_E < 0$ if $p_I \leq p_E^*$ and $a - c_o \geq 0$ or $p_I \geq p_E^*$ and $a - c_o \leq 0$, that is if $(p_I - c)(a - c_o) \leq (1 - \ell_t)(a - c_o)^2$. As a consequence, given this condition, $\nexists\tilde{w}_E > \bar{w} : \hat{\pi}_E(\tilde{w}_E, w_M) \geq 0$ ■

For p_I close to c, it will thus be sufficient to verify that the entrant cannot make nonnegative profits by having an infinitely small market share, that is by offering a surplus $w_E = w_I + \varepsilon$ with ε infinitely small. Suppose therefore that the entrant aims to have maximal per customer profits on an infinite small market share. Maximizing profits under this condition yields a usage fee set at the perceived marginal cost, thus $p_E^* = c + a - c_o$, and a fixed fee such that a customer with address $x = 1$, slightly prefers the entrant to the incumbent:

$$F_E = v_o + kv(c + a - c_o) - w_I - \varepsilon$$

with ε infinitely small. The entrant's profits on a customer with address $x = 1$ is then

$$\begin{aligned}\pi_E^1 &= v_o + kv(c+a-c_o) - w_I - \varepsilon - f \\ &\quad +(a-c_o)kq(c+a-c_o) + k\left[\frac{\ell_t}{\mu_t}q(p_I) - q(c+a-c_o)\right](a-c_o) \\ &= v_o - w_I - \varepsilon - f + k\left[v(c+a-c_o) + \frac{\ell_t}{\mu_t}q(p_I)(a-c_o)\right]\end{aligned}$$

The proof of the following lemma is now direct

Lemma 4 *If the entrant only serves customers with address $x = 1$ in the target segment, then, given the incumbent's strategy, the entrant's profits are minimal for an access charge a^* given by*

$$l_t kq(p_I) = \mu_t kq(c + a^* - c_o) \tag{28}$$

which is such that it is optimal for the entrant to set a usage price $p_E = c + a^* - c_o$ that balances flows between entrant and incumbent.

A corollary from lemma 4 and lemma 3 is that no entry will occur given w_I and p_I close to c, if and only if $\pi_E^1 < 0$ for a^*. Substituting a^* in the expression for π_E^1, we find thus that no entry occurs if and only if

$$\begin{aligned} \pi_E^1(a^*) &= v_o + kv(c + a^* - c_o) + kq(c + a^* - c_o)(a^* - c_o) - f - w_I - \varepsilon < 0 \\ &\Leftrightarrow \quad v_o + k(1-\delta)v(c) - f - w_I \leq 0 \end{aligned} \tag{29}$$

where δ is given by

$$\delta v(c) = v(c) - [v(c + a^* - c_o) + (a^* - c_o)q(a^* - c_o)]$$

or

$$\delta = 1 - \eta b^{\frac{\eta - 1}{\eta}} + (\eta - 1)b > 0$$

with $b = \dfrac{\ell_t}{\mu_t}$. As (p_I, w_I) must maximize the incumbent's profits in a candidate cornered market equilibrium, it follows that $p_I = c$. The incumbent's *per customer profits* are thus

$$\pi_I = v_o + kv(c) - f - 1/2\sigma - w_I$$

Substituting in (29), it follows that no entry occurs if and only if[21]

$$\pi_E^1(a^*) = \pi_I - \delta kv(c) + 1/2\sigma < 0 \tag{30}$$

As the incumbent must always make nonnegative profits in equilibrium, a necessary condition for the existence of a cornered market equilibrium is that

$$\delta kv(c) > 1/2\sigma$$

Finally, as (p_I, w_I) must maximize the incumbent's profits in a cornered market equilibrium, it follows that if the latter exists, w_I is such that profits π_I are maximal given restriction (30):

$$\pi_I = \pi_C \equiv \delta kv(c) + 1/2\sigma$$

■

[21] For simplicity, we assume that if the entrant is indifferent between entering or not entering the market, no entry occurs. One could, e.g., assume that entry involves a infinite small fixed cost ε.

Bücher des Forschungsschwerpunkts Marktprozeß und Unternehmensentwicklung

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