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ABSTRACT

Network Competition and Entry Deterrence*

We develop a model of logit demand that extends to a multi-firm industry the traditional duopoly framework of network competition with access charges. Firstly, we show that, when incumbents do not face the threat of entry and compete in prices, they inefficiently establish the reciprocal access charge below cost. This inefficiency disappears if incumbents compete in utilities instead of prices. Secondly, we study how incumbents change their choices under the threat of entry when they determine an industry-wide (non-discriminatory) access charge. We show how incumbents may accommodate all possible entrants, only a group of them, or may completely deter entry. When entry deterrence is the preferred option, incumbents distort upwards the access charges.

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Keywords: entry deterrence, interconnection and telecommunications

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1 Introduction

In the telecommunication sector, operators interconnect their networks to make consumers benefit from network externalities. Despite vigorous competition in the market, each operator is a monopolist over its subscribers' access lines. When a customer belonging to a certain network calls a consumer subscribed to another network, this other network is the only one that can terminate the call. The same situation appears the other way around, making interconnection a "two-way" access problem.[1] Because of this reciprocal need to terminate each other's calls, traditionally the termination bottleneck has not been seen with great concern by the regulatory authorities. It is expected that operators can reach some type of fair agreement, and, to avoid the possibility that operators establish a double mark-up, normally the regulators impose a requirement of reciprocity. Most countries, in fact, make interconnection mandatory but allow operators to determine bilaterally an identical termination charge. This paper draws a distinction between industries with a stable market structure and industries where entry can occur. We show that, in the first case, incumbents may reach efficient agreements over reciprocal access charges. However, when incumbents are threatened by the possibility of additional entry, they change their choices quite dramatically.

Recent literature has investigated the potential collusive role of access (wholesale) charges on consumer (retail) prices. The seminal works of Armstrong (1998), and Laffont *et al.* (1998) (henceforth ALRT) show that firms can use above-cost access charges as a collusive mechanism to obtain higher profits when firms compete in linear retail prices. However, this collusive result is not robust to more sophisticated pricing strategies. ALRT demonstrate that, with two-part retail prices, the access charge has a neutral effect on profits: any possible access profit would simply be passed on to customers via a reduction in their subscription fee.

The framework of ALRT has been extended in several directions. Gans and King (2001) show that when the operators price discriminate between on-net and off-net calls the profit neutrality of access charges does not hold any more. Firms can soften price competition and obtain higher profits by establishing access charges *below* cost. This runs opposite to the normal concern of regulators, who fear that access charges are set "too high" rather than "too low". Valletti and Cambini (2005) introduce investments in the ALRT framework and show that firms are keen on setting above cost access charges in order to weaken competition over investments. Jeon et al. (2004) and Berger (2005) study the role of access charges in the presence of call externalities.

One common feature of all these papers is that they consider a given market structure, almost invariably a duopoly.[2] The objective of this paper is to relax this

[1] For a complete review of this problem see Laffont and Tirole (2000), Armstrong (2002), Vogelsang (2003), and Peitz *et al.* (2004).

[2] Jeon (2005) is the only exception we are aware of. He considers a general model with many

assumption in order to consider the impact that the negotiation of access charges by incumbents may have on entry. The possibility of entry is clearly a relevant and realistic problem. In fixed telephony, technological progress keeps lowering entry barriers. In cellular telephony, although there are constraints imposed by the availability of electromagnetic spectrum, more efficient use of frequencies and additional releases of chunks of spectrum make entry also possible. In these markets it is likely that the incumbents consider what is the impact of the access charges that they negotiate on the profitability of entry by other firms.

We analyze the case where incumbent networks negotiate reciprocal access charges that are valid industry-wide, e.g., they apply both to incumbents and entrants. We develop a model with network-based price discrimination where profits are not neutral with respect to access charges. Incumbents recognize that the level negotiated for access charges affects ex post profitability, and thus the attractiveness of entry ex ante. We identify some circumstances where incumbents may want to distort the access charges away from its efficient level in order to deter entry of potential rivals. This result is obtained in a context where firms are symmetric after entry, and the level of access charges is non-discriminatory, i.e., it applies to all competing firms, both incumbents and new entrants. The non-discrimination feature is justifiable for its realism as many regulators, such as the European Commission or the Federal Communications Commission, adopt it. It also makes the problem interesting from an economic standpoint since, if discrimination was allowed instead, the incumbents would ask for a very high termination charge only for calls originated by potential entrants in order to weaken them.

Notice that a fully satisfactory model in which the access price is used as a deterrent must be an oligopolistic one, rather than simply a duopoly model where one firm is considered as the incumbent and the other firm as an entrant. With a single incumbent operator there is not much reason to have an access price in the absence of entry as there would be no interconnection. An oligopolistic model is also relevant from a policy perspective since regulators typically intervene less to regulate access prices under oligopoly.

This paper contributes to the literature in two ways. First, in order to study entry, we extend the traditional duopoly framework introduced by ALRT to allow the analysis of a multi-firm industry, using a model with logit demand.[3] One advantage of the logit formulation is that each network competes simultaneously with all other networks and not only with its immediate neighbors. This property is useful analytically in our multi-firm setting, making the study very tractable. We analyze

networks, but his interest is very different from ours. He focuses on non-reciprocal access charges that are set by a regulator instead of reciprocal and negotiated access charges, generalizing the Efficient Component Pricing Rule (ECPR). He also does not consider the possibility of entry.

[3]For a complete and detailed study of the logit demand models see Anderson *et al.* (1992). Doganouglu and Tauman (2002) analyze the negotiation of a reciprocal access charge in a duopoly with logit demands when operators establish linear prices.

the negotiation of the access charge under two kinds of strategic interaction among firms, when firms compete in prices and in utilities. Our analysis could also be carried under the Hotelling product differentiation framework that is usually is used in the literature on access charge, extended to the Salop circular city model.[4]

When firms compete in prices our findings generalize to the multi-firm case the result of Gans and King (2001) that operators are interested in setting the access charges below cost to soften competition. This result also implies that firms introduce inefficiencies as off-net calls are priced "too low", i.e., below marginal cost, and thus destroy some potential gains from trade. We show that this inefficiency does not arise when the strategic variable is utility instead of prices. In this case, incumbents in a multi-firm industry have an incentive to set termination charge at cost when they do not face the threat of entry.

The reason for studying both kinds of strategic interaction among firms is twofold. Firstly, the "trick" of using competition in utilities instead of prices is often used in the duopoly framework of ALRT and, more in general, in the literature on duopolistic price discrimination (e.g., Armstrong and Vickers, 2001; Rochet and Stole, 2002). This transformation of the problem simplifies computations and is innocuous in the absence of externalities. We conduct a comparison of the two kinds of competition in the context of our model of N-network competition, with and without externalities induced by off-net price discrimination. We show how competition in utilities and in prices yield different outcomes as long as termination prices differ from costs. In particular, when termination prices are below (above) cost, then competition in prices yields higher (lower) profits than competition in utilities. Secondly, because it is still true that competition in utility results in simpler expressions in the general case, we adopt it to simplify exposition when we deal with the entry game.

Our second contribution is to show the impact of entry on the negotiation of access charges carried out by the incumbents. We characterize how incumbents set access charges when they face entrants. We assume that the incumbents set an industry-wide level of the access charge, reflecting the regulator's concern for avoiding discriminatory charges that could distort competition or foreclose entry. Given the level of entry fixed costs, incumbents may decide to accommodate entry, or to accommodate only a subset of entrants and deter the others. The instrument at the incumbents' disposal to deter entry is the reciprocal access charge. This can be distorted away from the level that would maximize profits ex-post (i.e., after entry

[4] We have also analyzed Salop models under both competition in prices and utilities. In the Salop circular city model, we obtained closed-form solutions for the general case of N-network competition when firms compete in utilities. When firms compete in prices, however, the problem becomes more cumbersome in the presence of externalities, given the non-symmetric impact of a firm's price change on the rivals' market shares. We have obtained closed-form solutions only after having fixed the number N to specific values. In both cases, the results obtained are the same ones obtained under the logit formulation, which allows a more general treatment under both kinds of strategic interaction.

has occurred) in order to reduce the attractiveness of entry. We show that, when incumbents find it worthwhile to deter entry, they naturally distort the termination mark-up upwards. This occurs under both types of strategic interaction (prices or utilities). Thus, to the extent that incumbents can be challenged by entry, our results provide some support to the regulatory concern that access charges may be set "too high", rather than "too low". This result offers a conclusion opposite to Gans and King (2001) and has important implications in terms of regulatory policy.

The remainder of the paper is organized as follows. Section 2 analyzes a model of network competition among a generic number of firms. First, we assume that networks compete in prices, and then we study competition in utilities. Section 3 considers the negotiation of access charges when there is the possibility of entry. Section 4 discusses our main conclusions.

2 Negotiation of access charges in a multi-firm industry

We analyze the negotiation of reciprocal interconnection charges by a group of unregulated telecommunication operators that do not face the threat of entry. First, we consider the case where firms compete in discriminatory call prices and fixed subscription fees and afterwards we present the same model when firms compete in discriminatory call prices and net utilities.

Consider a group of $N \geq 2$ telecommunications firms that simultaneously compete against each other. All firms incur a fixed cost f to serve each subscriber. The marginal cost of providing a telephone call consists in the terminating and originating cost, c_0, and the conveying cost, c_1. As a result, the total marginal cost of an on-net call initiated and terminated on the same network is $c \equiv 2c_0 + c_1$. The firms also pay each other a reciprocal termination charge t when a call initiated on a network is terminated on a different network. Thus, for an off-net call, the economic marginal cost is still c but the "perceived" marginal cost for the network that initiates the call is $c_1 + c_0 + t$. Following the notation of Laffont *et al.* (1998b) we write the termination charge as $t = mc + c_0$, where, m represents the mark-up of interconnection charges relative to total marginal costs. Taking this notation into account, the off-net "perceived" marginal cost is then simply $c_0 + c_1 + t = c(1 + m)$.

The N firms have complete coverage and compete for a continuum of consumers of unit mass. Consumers call each other with equal probabilities. Market shares are derived using a logit model. Consumers have idiosyncratic tastes for each operator. A customer subscribed to firm i obtains the following quasi-linear utility

$$y + v_0 + v_i(p) + \tau_i,$$

where y is the income of the consumer, v_0 is a fixed utility term derived from subscription that is assumed to be high enough to guarantee full coverage (i.e., consumers never buy the outside option) and $v_i(p) \equiv \max_q \ u_i(q) - pq$ denotes the net indirect utility from making q calls at a price p and is discussed below. These terms are non-stochastic and reflect the population's tastes. The term τ_i is randomly drawn and reflects the idiosyncrasies of individual tastes. The random taste parameter is known to the consumer but is unobserved by the firms.

Firms offer multi-part tariffs and price discriminate between on-net and off-net calls. Consumers pay a tariff with the following structure

$$T_i(q_{ii}, q_{ij}) = F_i + p_{ii}q_{ii} + \sum_{j=1, j\neq i}^{N} p_{ij}q_{ij},$$

where F_i is the fixed subscription fee that consumers pay to firm i, p_{ii} and q_{ii} are the price and quantity of on-net calls, and p_{ij} and q_{ij} are the price and quantity of off-net calls from network i to network $j \neq i$. The net surplus for being subscribed to network i is

$$w_i(p_{ii}, p_{ij}, \tau_i) = \sum_{j=1}^{N} \alpha_j v(p_{ij}) - F_i + \tau_i, \tag{1}$$

where α_j denotes the market share of firm j. A consumer subscribes to firm i when $w_i(p_{ii}, p_{ij}, \tau_i) \geq w_j(p_{jj}, p_{ji}, \tau_j)$. The logit demand functions are obtained by assuming that all τ_i are i.i.d. and follow the double exponential distribution with zero mean. As shown by Anderson et al. (1992), in this case the market share α_i of firm i is given by

$$\alpha_i = \frac{exp[\frac{\sum_{j=1}^{N} \alpha_j v(p_{ij}) - F_i}{\sigma}]}{\sum_{k=1}^{N} exp[\frac{\sum_{j=1}^{N} \alpha_j v(p_{kj}) - F_k}{\sigma}]}, \tag{2}$$

where σ is a positive constant, which is positively related to the degree of product differentiation. It can be shown that when $\sigma \rightarrow 0$ the variance of τ_i also tends to zero. In this case, the multinomial logit reduces to a deterministic model. By contrast, when $\sigma \rightarrow \infty$, the variance of τ_i tends to infinity and all alternatives are equally possible.

We consider the following timing of the game. First, the N firms decide co-operatively the common reciprocal mark-up m for termination. Second, firms determine their multi-part tariffs by competing in call prices and fixed subscription fees or net utilities. Third, consumers subscribe to one network in the way described above.

2.1 Competition in prices

We solve the model by backward induction. First, we determine the multi-part tariffs in the second stage of the game and then we study how the networks negotiate over the reciprocal access charge. To begin with, we state without proof the well-known result that firms set call prices equal to the perceived marginal costs. This result is general both to competition in call prices and fixed fees and to competition in call prices and net utility.[5] The call prices offered by firm i are: $p_{ii} = c$ on-net and $p_{ij} = c(1+m)$ off-net. With these prices the profit of firm i can be written as

$$\pi_i = \alpha_i(F_i - f) + \sum_{j=1, j\neq i}^{N} \alpha_i \alpha_j (t - c_0) q(p_{ij}) = \alpha_i(F_i - f) + \sum_{j=1, j\neq i}^{N} \alpha_i \alpha_j mcq(c(1+m)). \tag{3}$$

Differentiation of the profit function with respect to the fixed subscription fee of network i leads to the following first order condition

$$\frac{d\pi_i}{dF_i} = \frac{\partial \pi_i}{\partial F_i} + \frac{\partial \pi_i}{\partial \alpha_i}\frac{\partial \alpha_i}{\partial F_i} + \frac{\partial \pi_i}{\partial \alpha_j}\frac{\partial \alpha_j}{\partial F_i} = 0,$$

where the market share α_i is given by equation (2). In order to compute this condition in a symmetric equilibrium when $\alpha_i = \alpha_j = 1/N$, it is useful to consider first the following results,

$$\frac{\partial \alpha_i}{\partial F_i} = -\frac{N-1}{N[N\sigma - (v(c) - v(c(1+m))]}; \qquad \frac{\partial \alpha_j}{\partial F_i} = \frac{1}{N[N\sigma - (v(c) - v(c(1+m))]}.$$

Solving the first order condition we obtain in a symmetric equilibrium

$$F_i = f + \frac{N\sigma - (v(c) - v(c(1+m))}{N-1} - \frac{cm(N-2)q(c(1+m))}{N}. \tag{4}$$

When $m = 0$, equation (4) simplifies to

$$F_i = f + \frac{N\sigma}{N-1},$$

[5] If, on the contrary, firms offered call prices different from perceived marginal cost, they could always make more profits by offering calls at the perceived marginal cost and adjusting the fixed fee/net utility. This result arises because all customers are identical with respect to call usage. This is found in most of the literature on two-way access pricing in the typical Hotelling framework with multi-part tariffs, as all consumers have a common call demand and only differ from an additive parameter of horizontal differentiation. See also Yin (2004) and Reitzes and Woroch (2005) for related results in models with logit demands.

which further simplifies to $F_i = f + 2\sigma$ when $N = 2$. This result implies that, in a duopoly with zero mark-ups, the fixed subscription fee is simply equal to the direct subscription cost plus a term that reflects idiosyncratic tastes and is equivalent to the standard Hotelling term of horizontal differentiation.

Returning now to the general case, the next proposition shows how the networks establish the mark-up m in the first stage of the game.[6]

Proposition 1. *When incumbents compete in discriminatory call prices and subscription fees they establish a reciprocal access charge below cost, $m < 0$, and earn a profit strictly greater than $\sigma/(N-1)$.*

Proof. Substituting the subscription fee from equation (4) in the profit function (3) yields

$$\pi_i(N, m) = \frac{N\sigma - (v(c) - v(c(1+m))}{N(N-1)} + \frac{cmq(c(1+m))}{N^2}. \tag{5}$$

Differentiating the profit function with respect to the mark-up m and considering that $v'(c(1+m)) = -q(c(1+m))$ we obtain

$$\frac{\partial \pi_i}{\partial m} = \frac{c[cm(N-1)q'(c(1+m)) - q(c(1+m))]}{N^2(N-1)}. \tag{6}$$

Evaluating this expression at $m = 0$, equation (6) can be simplified to

$$\frac{\partial \pi_i}{\partial m} |_{m=0} = -\frac{cq(c)}{N^2(N-1)} < 0.$$

Therefore, in equilibrium, $\frac{\partial \pi_i}{\partial m} |_{m=0} < 0$ and the mark-up m is always chosen negative. Also note that, when $m = 0$, the profit function in (5) takes the following expression:

$$\pi_i = \frac{\sigma}{N-1} \tag{7}$$

which represents a lower bound to the profit when $m < 0$. ■

This proposition generalizes the findings of Gans and King (2001) to a multi-firm industry when there are logit demands. The intuition is that, when m is negative, customers want to subscribe to smaller networks, because they would place relatively more off-net calls that are cheaper than on-net calls. When this happens, firms are

[6] We assume that an equilibrium exists, which requires σ to be sufficiently high, i.e., products are sufficiently differentiated. See De Palma and Leruth (1993) for a proof of this result in a logit framework with network externalities.

less interested in building market share. As a result of the negative mark-up, price competition is mitigated and higher profits are obtained.

In our set up efficiency dictates that call prices should be equal to marginal costs. While this is achieved in equilibrium for on-net calls, a direct consequence of Proposition 1 is that off-net prices are inefficiently low as $p_{ij} = c(1+m) < c$ and "too many" off-net calls are placed. This discussion is summarized in the following corollary.

Corollary 1. *When incumbents compete in discriminatory call prices and subscription fees, the negotiation of reciprocal access charges leads to inefficiently low off-net retail prices.*

Proposition 1 only establishes that operators would choose an access charge below cost, but it does not characterize the optimal reciprocal charge. We can find sufficient conditions that result in a "bill-and-keep" system, that is an arrangement where incumbents agree on $t = 0$ and do not pay or receive any termination charge.[7]

Corollary 2. *Sufficient conditions for a "bill-and-keep" system to emerge are: i) c is sufficiently small, or ii) call demand is sufficiently inelastic.(iii) A "bill-and-keep" system is more likely to be adopted the fewer the number of competing firms.*

Proof. The optimal mark-up is determined by equation (6). (i) Take the case of low c ($c \longrightarrow 0$). We can characterize the asymptotic behavior of equation (6) by concentrating only on the higher-order terms. In this case equation (6) simplifies to

$$\frac{\partial \pi_i}{\partial m} \mid_{c \longrightarrow 0} = \frac{-cq}{N^2(N-1)},$$

which is always negative for any value of m, thus operators agree an a "bill-and-keep" system. By continuity, a "bill-and-keep" system is chosen for a sufficiently low value of c.

(ii) Denote as ε the elasticity of demand for calls. Imagine $\varepsilon \rightarrow 0$ (i.e., $q' \rightarrow 0$). Equation (6) can be rewritten as

$$\frac{\partial \pi_i}{\partial m} \mid_{\varepsilon \longrightarrow 0} = \frac{-cq}{N^2(N-1)},$$

which is always negative for any value of m. Therefore operators negotiate the lowest possible termination charge, i.e., they agree an a "bill-and-keep" system. By continuity, a "bill-and-keep" system is chosen for a sufficiently low value of ε.

(iii) If an interior solution to equation (6) exists (i.e., m is negative but not as low as a "bill-and-keep" system*)*, the optimal m is given by:

[7] We do not allow for negative access charges, i.e., $t < 0$ is ruled out. See Section 3 below for a discussion.

$$m = \frac{q(c(1+m))}{m(N-1)q'(c(1+m))}.$$

Using the definition of elasticity, and the fact that at equilibrium $p = c(1+m)$, the previous expression can be re-arranged as

$$m = -\frac{1}{(N-1)\varepsilon + 1}$$

which is lower (i.e., closer to a "bill-and-keep" system) the lower is N. ■

This finding shows that a "bill-and-keep" system may emerge purely for strategic reasons. Obviously, this result would be reinforced by taking into account transaction costs, e.g., billing and monitoring costs. Yet this conclusion is somewhat unappealing for two reasons. First, incumbent operators distort off-net prices, thus some potential gains from trade are lost while they could be reached if the termination charge was set at cost rather than below cost. Second, regulators are typically concerned that the mark ups set by the operators may be too high rather than too low, a result that does not arise in our model. In the next section we show that the first intuition is actually correct and firms set efficient access charges if they compete in utilities instead of prices. Section 3 confirms the regulators' concern about "too high" access charges to the extent that incumbents are challenged by potential entrants.

2.2 Competition in utilities

We now analyze the determination of the reciprocal access charges when firms compete in discriminatory call prices and in utilities. From equation (1), and using again the result that call prices are set equal to the perceived marginal cost, the expected fixed subscription fee can be written as follows:

$$F_i = \alpha_i v(c) + \sum_{j=1, j\neq i}^{N} \alpha_j v(c(1+m)) - w_i.$$

Recall from the Introduction that competition in utilities is studied for two reasons. Firstly, we want to compare it with competition in prices, with and without externalities, to check under what circumstances one could reasonably assume that the two kinds of strategic interaction yield the same outcomes and, if they do not, how they differ. Secondly and more importantly, we show below how competition in utilities delivers simpler expressions than competition in prices and we use this as an ingredient to the entry game studied in Section 3 to simplify exposition.[8]

Consider the profit function in equation (3). After substitution of the market shares α_i and α_j as defined by equation (2) and the subscription fee defined above, we differentiate the profit with respect to the net utility w_i. Assuming a symmetric equilibrium with $w_i = w_j$, for $j = 1, ..., N$, we obtain

$$w_i = v(c) - f - \frac{N}{N-1}\sigma + \frac{(N-2)[cmq(c(1+m)) + v(c(1+m)) - v(c)]}{N}. \quad (8)$$

Note that when $N = 2$ this simplifies to $w_i = v(c) - f - 2\sigma$. In the general case, the fixed subscription fee can be immediately derived from the equilibrium net consumer utility:

$$F_i = f + \frac{N}{N-1}\sigma - \frac{(N-2)cmq(c(1+m)) + v(c) - v(c(1+m))}{N}. \quad (9)$$

When $N = 2$ the subscription fee simplifies to $F_i = f + 2\sigma - [v(c) - v(c(1+m)]/2$. Doganoglu and Reichhuber (2004) show that in a Hotelling duopoly the access charge only affects the off-net traffic (via the off-net calling price) but not the net utility w_i. Equation (8) show that this feature also arises in our model when $N = 2$. The intuition for their result is that any losses or gains in consumer surplus due to above or below marginal cost pricing for off-net calls are fully compensated by the firms through the adjustment of the subscription fee. The neutrality of the mark-up m on the net utility w_i does not generalize for $N > 2$ in our logit model. In fact, we show below that an increase of m above 0 lowers the subscription fee but has a negative effect on the net utility offered to consumers in equilibrium.

The impact of m on F_i can be seen from (9): if $m > 0$, then $v(c) > v(c(1 + m))$ thus the last term in (9) is negative overall and the subscription fee decreases with a positive mark-up. This has a positive impact on the utility offered to customers. However, an increase in m also leads to an increase in the price of off-net calls, and thus the indirect utility from off-net calls decreases. From (8) it is clear that the net effect is negative as

$$\Delta = cmq(c(1+m)) - [v(c) - v(c(1+m))] < 0, \quad (10)$$

[8]If one wanted to take the utility strategy space at face value, firms would need to find a way to commit to utility levels. Once these are announced and market shares are realized, subscription fees would then be computed ex post according to the last expression, which is not a very realistic mechanism overall.

where the strict inequality stems from the fact that Δ represents the classic "dead-weight loss" when prices differ from marginal costs.[9] Similarly, it can be shown that if $m < 0$ then the subscription fee increases with the negative mark-up and, overall, net utility *still* decreases.

We are now a position to determine the negotiation of the access mark-up in the first stage of the game.

Proposition 2. *When incumbents compete in discriminatory call prices and net utilities they establish a reciprocal access charge with a zero mark-up over cost,* $m = 0$.

Proof. Simplifying the profit function in equation (3) with the equilibrium value for w_i from (8) we obtain

$$\pi_i(N, m) = \frac{\sigma}{N-1} + \frac{\Delta}{N^2} \tag{11}$$

where Δ is given by (10), and $\Delta < 0$ for all $m \neq 0$ and $\Delta = 0$ for $m = 0$. We can immediately conclude that, for any number N of incumbents, $m = 0$ is the unique solution that maximizes profits since it minimizes the deadweight loss Δ. ■

In order to understand this proposition,[10] note that, when the incumbents set a positive termination mark-up, two effects arise. The mark-up has a positive direct effect on profits as it generates termination revenues. However, these termination revenues are dissipated by a negative indirect effect: competition makes the firms concede utility to consumers pushing down fixed subscription fees. In addition, the fixed subscription fee must compensate for the loss in net utility from making off-net calls. Overall, the indirect effect more than prevails over the direct effect and, as a result, a positive mark-up reduces profits. Similarly, a negative mark-up allows to increase fixed fees because consumers pay less for off-net calls, but it induces termination losses that cannot be recovered via an equal increase in fixed fees.

All in all, when firms compete in net utilities the optimal mark up is exactly set at zero. The "perceived" marginal cost for off-net calls then coincides with the true economic marginal cost, and off-net prices induce an efficient number of calls as with on-net calls, $p_{ii} = p_{ij} = c$. For a given number of competing firms, it then follows that the industry is able to "self-regulate" as private negotiations over access charges induce efficiency.

Corollary 3. *When incumbents compete in discriminatory call prices and net utilities, the negotiation of reciprocal access charges is efficient.*

[9] To confirm that Δ, as expressed by equation (10), is the "deadweight loss" when $m \neq 0$ and thus $p = c(1+m) \neq c$, notice that the first term on the RHS of (10) is $(p-c)q = cmq$, i.e., it corresponds to the change in firm's profits, while the second term is the change is consumer surplus.

[10] Armstrong (2002, fn 102) also notes this finding in a Hotelling duopoly setting with competition in utilities.

We end this section by conducting a comparison of the equilibrium profits under the two modes on competition, in prices and net utilities.

Proposition 3. *(i) With exogenously set access charges, competition in prices and competition in utilities yield the same equilibrium profits if* $m = 0$. If $m < 0$ *(respectively,* $m > 0$*), competition in prices yields strictly higher (respectively, lower) profits than competition in utilities. (ii) With endogenous access charges, competition in prices yields strictly higher profits than competition in utilities for any value of* N*.*

Proof. (i) Profits when competition is in prices are given by equation (5), while equation (11) is valid when competition is in utilities. Fixing a certain mark-up m and taking the difference we obtain:

$$\pi_i(N, m \mid prices) - \pi_i(N, m \mid utilities) = -\frac{v(c) - v(c(1+m))}{N^2(N-1)}.$$

The RHS is zero when $m = 0$, while it is positive (negative) when $m < 0$ ($m > 0$). (ii) When m is endogenous, firms choose different mark-ups under the two kinds of strategic interaction. When firms compete in utilities, they choose $m = 0$, while they choose $m < 0$ when they compete in prices. Thus a strictly lower bound to profits under price competition is found when $m = 0$. Putting this together, and recalling result (i), we find that

$$\pi_i(N, m < 0 \mid prices) > \pi_i(N, m = 0 \mid prices) = \pi_i(N, m = 0 \mid utilities). \blacksquare$$

The comparison conducted in Proposition 3 is interesting for several reasons. First, it is of interest to compare equilibrium profits under the two competition modes when m is set at some exogenous level as this may correspond to m being exogenously regulated. The specific value $m = 0$ is relevant since it is chosen by regulators in many practical circumstances. In addition, the particular level $m = 0$ removes calling externalities that would otherwise exist because of price differences between on-net and off-net calls when $m \neq 0$. Without externalities, competition in prices or in utilities yield the same outcome. On the contrary, when $m < 0$, customers would prefer to belong to a relatively smaller network, but this allows firms to soften price competition and extract higher fixed subscription fees from their customers. Under utility competition, firms have to compensate their customers for the loss in off-net calling surplus, thus they make less profits than under price competition when $m < 0$. Conversely, when $m > 0$, price competition is made tougher and the loss in profits is greater under price competition than competition in utilities (part (i)). In addition, the proposition shows that, when incumbents choose the common termination mark-up endogenously, they can do better (i.e., achieve higher profits despite a decrease in total welfare) in the price setting game than in the utility setting game (part (ii)). Under competition in utilities firms do not want to introduce externalities by distorting the termination mark-up, otherwise they would have to compensate their customers. This differs from competition in prices when there is a chance to introduce externalities via negative mark-ups to soften competition.

3 Zero mark-ups or entry deterrence?

The previous section has shown that competing incumbent network operators that do not face potential entrants choose termination charges either at or below cost. The particular value for the termination charge depends on the type of strategic interaction among operators. While these findings have an impact on efficiency, in our model access charges never turn out to be chosen above cost, which is one of the main concerns of regulators. This section examines the robustness of our results when entry is possible. We investigate the setting of an access charge that is non-discriminatory, i.e., it applies both to incumbents and to potential entrants.[11] The problem would not be very challenging if an incumbent monopolist or a group of incumbents could discriminate by setting very high termination rates charged selectively only to calls originated by entrants. In this case, as the incumbent monopolist or the group of incumbents are worse off with an increase in the number of competitors, they will discriminate against entrants and possibly foreclose entry.

The introduction of a non-discriminatory requirement makes the determination of the reciprocal access charge an interesting problem from an economic point of view. The incumbents face a trade-off. If they set the efficient (i.e., industry profit maximizing) mark-up along the lines described in the previous section, they maximize profits ex post for a given number of firms. This makes entry more appealing ex ante, thus potentially attracting too many entrants and losing profits as a consequence. Faced with this threat, incumbents may want to distort the mark-up away from the efficient one in order to make ex post competition tougher which limits the attractiveness of entry. Notice that the logit model we employ implies that every firm is symmetric ex post, i.e., after entry has occurred. Thus the *only* possible reason to distort the mark-up is because of its impact on the entry game, which is the correct benchmark given our interest in entry deterrence. If successful entrants were asymmetrically placed, there could be of course additional reasons to try to affect the terms of interconnection ex post (Carter and Wright, 2003).

To analyze how incumbents negotiate ex ante the industry access charge we consider the following four-stage game. At stage one, incumbent networks establish the interconnection arrangement. The interconnection terms apply to all industry

[11] In the United States, the 1996 Telecommunications Act establishes that the access charges should be non-discriminatory. The European Union establishes the same principle in the Access Directive 2002/19/EC.

participants, including the firms that enter after the agreement has been reached.[12] At stage two, entrants decide whether or not to enter the industry. If they enter, they pay a fixed entry cost K. This cost is only paid by actual entrants and it is the same for all of them. Incumbents do not have to pay this cost (or have already sunk it). At stage three and four, all operators (incumbents and actual entrants) compete against each other and customer subscribe in the way described in the previous section.

Since the last two stages are identical to the games analyzed in Section 2, the equilibrium profits in stage 3 are given by equation (5) or (11), depending on the type of strategic interaction being considered. The profit functions depend only on the total number N of competing firms and on the reciprocal termination mark-up, m. Thus the stage 3 equilibrium profit per firm can be written as $\pi(N, m)$. Now consider a potential entrant at stage 2. It decides to enter if and only if, by becoming one of the N competing firms, it is able to recover its fixed entry costs. Entry stops when fixed costs cannot be recovered by ex post profits. Thus entry in stage 2 can eventually occur if it is possible to find a range $\pi(N, m) > K$ compatible with entry. As K declines, more firms are expected to enter, other things equal. In stage 1 the incumbents, by choosing m, can indeed affect the level of entry.

In the analysis that follows we assume that stage-3 equilibrium profits satisfy the following properties:

(1) The profit function $\pi(N, m)$ is continuous in m and it is maximized for $m(0)$, for any number N of competing firms; $m(0) < 0$ when firms compete in prices and $m(0) = 0$ when firms compete in utilities.

(2) The profit function declines with the number of competing firms, for a given mark-up m: $\pi(N, m) > \pi(N + 1, m)$.

The notation $m(0)$ above indicates the optimal mark-up chosen by incumbents when they do not face entry, so that there are "0" possible entrants. Property (1) is clearly satisfied by the model presented in Section 2 as it is simply a re-statement of Proposition 1 and 2. Property (2) is quite natural, and it is easy to prove that the equilibrium profit functions of Section (2) satisfy it, although parameter restrictions would be required.[13]

From now on, we concentrate on the game when the strategic variable is net utilities since it generates simpler results, but the arguments exposed below apply

[12] Given the ex-post symmetry of the logit model, if incumbents negotiate an access charge among themselves that differ from the conditions offered to new entrants, this would be immediately be considered as discriminatory. Our negotiation set-up could also be re-interpreted as a set of bilateral negotiations among identical firms under the non-discrimination requirement.

[13] From (11), when fims compete in utilities, it is immediate to see that it is sufficient that either σ or N are high enough for Property (2) to hold true. It is possible to prove that these are also sufficient conditions in the case of price competition when (5) applies.

also when firms compete in prices.[14] Before studying the general case, we illustrate progressively the mechanisms at work. This allows us to introduce some additional notation.

To start with, imagine there are only two incumbents. If they are not threatened by entry, they choose $m(0) = 0$ and earn $\pi(2, m(0))$ each. However, incumbents may behave differently when they face potential entrants. If the entry cost is very high, the entry threat is not credible, thus the two incumbents keep charging the optimal $m(0) = 0$. In particular, the entrant cannot hope to recover its fixed cost when this is higher than $K_2^b = \pi(3, m(0))$. For values of the entry cost above this level, $K > K_2^b$, the entry of the third firm is "blockaded", even at the zero mark-up which is the most convenient for ex-post profitability. In other words, the industry is a "non-contestable natural duopoly" and the two incumbents do not distort the mark-up.

When $K < K_2^b$ the incumbents decide to modify the mark-up m. If the incumbents kept charging the efficient mark-up $m(0) = 0$, this would trigger entry of a third firm and the incumbents' profits would suddenly be lowered from $\pi(2, m(0))$ to $\pi(3, m(0))$. Instead of accepting this discrete jump in profits, the incumbents have a better option: they can increase the industry termination mark-up in order to make entry unprofitable. Let us denote with $m(1)$ the resulting value of the mark-up that deters the first possible entrant. This mark-up is found by equating the gross (ex post) profit of the potential entrant under the distorted mark-up $m(1)$ with the entrant's entry cost, i.e., the mark up $m(1)$ is found by solving implicitly $\pi(3, m(1)) = K$. Having deterred the first possible entrant, the incumbents earn $\pi(2, m(1)) > \pi(3, m(0))$. The inequality clearly holds for K close enough to K_2^b, because, when K approaches K_2^b, $m(1)$ must approach $m(0)$ by construction and $\pi(2, m(0)) > \pi(3, m(0))$. The continuity of the profit function ensures that there is always a range of fixed costs below K_2^b such that deterrence must be the preferred option. In this range of entry costs, we can rightly talk of "entry deterrence", as in the absence of any strategic manipulation of the mark-up the industry would be a "natural triopoly". Instead, incumbents deter entry and distort the termination mark-up.

When the entry cost is lower than K_2^b it is necessary to distort even more the mark-up if the incumbents want to keep the entrant out. However, this distortion also lowers the profit of the incumbents themselves. In fact, at some stage the incumbents may give-up the deterrence strategy, allowing entry of the third firm and set the optimal $m(0)$ for a triopoly. The value of m at which incumbents accommodate entry is defined by the indifference condition $\pi(3, m(0)) = \pi(2, m^*)$. The corresponding limiting fixed entry cost paid by the potential entrant is defined as $K_2^d = \pi(3, m^*)$. Thus, for all values of $K > K_2^d$, entry is deterred. For lower

[14] For instance, $m(0) = 0$ when firms compete in utilities, $\forall N$; while $m(0) < 0$ when firms compete in prices, but the precise value of m may depend on N (but not always: for instance, Corollary 2 gives conditions such that m is always chosen to deliver a "bill-and-keep", independently from N).

values of K there are two possible scenarios. The first scenario is the case when $K_2^d > K_3^b = \pi(4, m(0))$. That is, the fixed entry cost associated to the mark-up that makes the two incumbents indifferent between deterring the third firm and accommodating it with an optimal zero mark-up (K_2^d) is bigger than the fixed entry cost that blocks the entry of a fourth firm (K_3^b). As a result, a second entrant (the fourth firm overall) cannot recover its fixed cost. When this occurs, and summing up all the previous results, the incumbents set the access charge in the following way:

(1) if $K > K_2^b$ the two incumbents set $m(0) = 0$ and entry of the third firm is "blockaded";

(2) if $K_2^d < K < K_2^b$ the two incumbents set $m(1) > m(0) = 0$ and entry of the third firm is "deterred". The mark-up distortion increases for lower values of K;

(3) if $K_3^b < K < K_2^d$ the two incumbents set $m(0) = 0$ and entry of the third firm is "accommodated". These three firms maintain the efficient zero mark-up and the fourth firm is "blockaded";

(4) if $K < K_3^b$, the same reasoning can be repeated, now with three "effective" incumbents who have to decide whether to deter or accommodate the entry of the fourth firm, and so on.

The second scenario occurs when $K < K_2^d < K_3^b$. Now the two incumbents should *not* accommodate the third firm and set a zero mark-up, otherwise this will trigger the *simultaneous entry of both the third and fourth firm.* Instead, the incumbents can do better. They should deter both potential entrants. They achieve it by distorting the mark-up even beyond m^*, to the level that just deters both entries, which is found by solving $\pi(4, m) = K$. The value of m that solves this equation is denoted by $m(2)$, as it is the limiting mark-up that deters the first two possible entrants. The incumbents, having deterred both entrants, then earn $\pi(2, m(2))$, which is the maximum profit that can be obtained in a duopoly by distorting m.

Figure 1 illustrates the previous reasoning with an example when firms compete in utilities.[15] We consider that there are two incumbents and only two potential entrants. The left panel plots the ex-post gross profits as a function of the mark-up. The three curves show the profits corresponding to the possible market structures $N = 2, 3, 4$. The right panel describes the optimal mark-up as a function of the fixed entry cost K that is incurred by the entrants. In the example, $K_2^b = 0.2$; when $K > K_2^b$ entry is not a threat and incumbents set $m(0) = 0$. On the other hand, $K_2^d = 0.015\overline{5} > K_3^b = 0.015$. As a result, the incumbents find it optimal to deter the third firm for $K_2^d \leq K < K_2^b$. In the range $K_3^b \leq K < K_2^d$ the

[15] Figure 1 uses a linear demand function for calls $1 - p$ and a total marginal cost $c = 0.2$.

fourth firm is "blockaded", thus the three effective competing firms do not distort the mark-up and set again $m(0) = 0$. Finally, when $K < K_3^b$ the incumbents accommodate the first entrant but not the second: m is distorted and the second entrant is deterred. Only when K is very low, $K < K_3^d = 0.0125$, the incumbents give up any deterrence strategy, accommodate both entrants, and set an industry mark-up equal to $m(0) = 0$.

Insert Figure 1: Profits (left panel) and mark-ups (right panel)

Notice that Figure 1 only reports positive distorted mark-ups, while in principle there could be also symmetric solutions for negative values. These options are not reported for two reasons. First, the marginal cost is typically not very high in telecommunication networks. Hence negative mark-ups can easily imply negative termination charges which are difficult to enforce.[16] Operators may be limited to negative values that are bounded by a "bill-and-keep" system and thus the attempts to deter entry would lose their power compared to positive mark-ups that do not face a similar problem. Second, the previous argument is reinforced if the strategic variable is price instead of utility. As we have explained in Section 2, when operators compete in prices, they would already set negative mark-ups in the absence of entry threats, and in some cases this goes as far as a zero termination charge (a "bill-and-keep" system). In order to diminish the ex post profitability of entrants, operators can just try to distort the optimal mark-up upwards and not downwards. In other words, distortions away from the optimal "collusive" charge to deter entrants are much easier and natural to implement by going to higher values of the termination charge.

We complete the analysis with our final result that illustrates how a general number of incumbents establish the industry-wide access charge when they face the threat of entry. Consider that there are n incumbents and a large number of possible entrants. Denote as K_{n+j}^b the limiting fixed entry cost that blocks the entry of the $j+1$ entrant even at the optimal mark-up, i.e., $K_{n+j}^b = \pi(n+j+1, m(0))$, $j = 0, 1, ...$ The following proposition describes how the n incumbents set the termination mark-up and affect subsequent entry.

Proposition 4. Imagine the fixed entry cost is in the range $K_{n+j+1}^b < K < K_{n+j}^b$, $j = 0, 1, ...$ The n incumbents set an industry-wide reciprocal termination mark-up $m(d)$ that deters $d \leq j$ entrants, and accommodate $j - d$ entrants, where

[16]Negative access charges would open the door to very strategic behavior. For instance, an operator could always receive an arbitrarily large amount of money from the rival by placing an arbitrarily large number of calls itself on the rival's network.

$m(d)$ is the solution of

$$\pi(n+j-d+1, m) = K, \quad \text{where } d = 0, 1, ..., j.$$

The optimal mark-up is the one that maximizes the incumbents' ex-post individual profit:

$$\pi(n+j-d, m(d))$$

and satisfies the following properties: $m(0) < m(1) < ... < m(j)$.

Proof. First, note that when $K^b_{n+j+1} < K < K^b_{n+j}$ and $m(0)$, j entrants would enter while the $(j+1)$-th entrant would be blocked. Thus, the "natural" market structure in this range comprises $n+j$ firms. The n incumbents must decide whether to accommodate all of potential entrants, just a subset or none of them. If they accommodate all of them, then $d = 0$ and there is no strategic reason to distort the mark-up and the incumbents earn $\pi(n+j, m(0))$. If the incumbents deter all potential entrants then they must guarantee that even the first possible entrant does not want to enter. For this reason, they set the mark-up $m(j)$ that deters entry of the first firm that brings the industry structure to $n+1$ firms: $\pi(n+1, m) = K$. Having deterred all potential entrants, the incumbents would earn an individual profit $\pi(n, m(j))$. In between these extreme options, the incumbents can find profitable to deter only a subset of d possible entrants and accommodating $j-d$ of them. To avoid entry of an additional firm, the $n+j-d$ effective competitors establish $m(d)$ where $\pi(n+j-d+1, m(d)) = K$. Each of the incumbents then earn the profit corresponding to $n+j-d$ competing firms, $\pi(n+j-d, m(d))$. The most profitable strategy among these three possibilities depends on the shape of the profit function π. ■

4 Conclusions

This paper has proposed a model of competition among multiple network operators, extending the traditional duopoly models. We have analyzed how incumbents networks negotiate reciprocal access charges under different entry scenarios. When the incumbents do not face the threat of entry, they establish an inefficient access charge below cost if they compete in prices and an efficient access charge equal to cost if they compete in utilities.

These results are general in the sense that they do not depend on the number of competing networks. Yet these findings do not seem to confirm the typical regulatory concerns that access charges are likely to be set too high (i.e., above cost) if they are left unregulated. The second part of the paper has shown that this view can be reconciled with our model when we allow for the possibility of entry. Under an entry scenario, incumbent networks may decide to set an industry-wide (non-discriminatory) access charge that accommodates all possible entrants, only a group of them, or may decide to use the access charge in order to completely deter entry. The optimal strategy for the incumbents is the solution of a trade-off. They can establish the efficient mark-up that maximizes profits given the ex post number of firms, but this would increase the profitability of entry. To avoid this, incumbents can distort the efficient mark-up, at the loss of their own ex post profits.

In order to assess the validity of our analysis, we emphasize that this trade-off emerges regardless of the type of strategic interaction among incumbents. We have also explained that the incumbents distort the mark-up upwards under both kinds of strategic interaction (prices or utilities) when it is worthy for them to deter entrants. However, the particular magnitude of the distortion (equivalently, the particular level of the entry fixed cost that makes deterrence profitable) will be different in each case, since ex-post profits are different when firms compete in prices than in utilities.

Our analysis shows that incumbent networks establish the reciprocal access charge depending on the magnitude of the fixed entry costs born by potential entrants. If these costs are high enough, the incumbents may find it profitable to fix an access charge that deters all potential entry. When the fixed entry cost is reduced, the incumbents may find it profitable to set an access charge that permits the entry of a whole group of entrants. This result is similar in spirit to Bernheim (1984) when he writes that "successful deterrence does not depend upon industrial concentration in the manner which one might expect: the stable sizes of an industry (i.e., levels of concentration at which operating firms successfully deter entry) tend to be staggered (for example, no further entry occurs if and only if there are two, six, ten or fifteen firms)". This dynamic process is of particular interest in an industry such as telecommunications: Fixed costs of entry can be assumed to decrease over time because of some exogenous technological progress, which provides an engine to our mechanism that generates "staggered" market structures.

Notice that anytime incumbents increase the access charge above cost in order to deter entrants, this introduces allocative distortions for calls, as the off-net price is set above marginal cost. This behavior also limits the gains from entry for consumers. Thus above-cost access charges have bad properties from a normative point of view. A general welfare analysis, however, is more complicated since in standard logit models there is typically excessive entry as the business stealing effect is prevailing over the non-appropriation of consumer surplus. Thus entry-deterrence via distorted mark-ups may improve welfare to the extent that it limits excessive entry.

The possibility of setting strategically the access charge to deter entry is crucially based on the commitment of the incumbents of not modifying the access charge, once entry has occurred. Clearly, if the mark-up was renegotiated after entry, then the actual incumbents will always establish the ex-post profit maximizing mark-up. It is the assumption of commitment that creates opportunities for strategic behavior.

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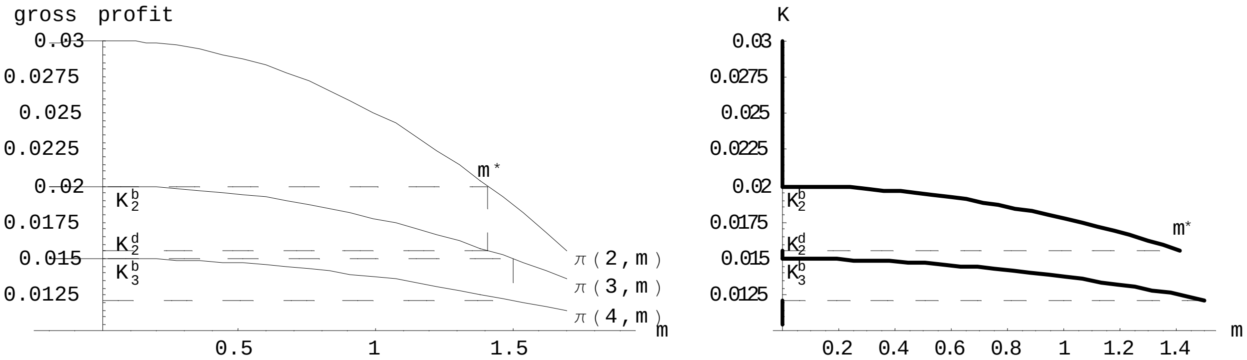

gross profit
0.03
0.0275
0.025
0.0225
0.02
0.0175
0.015
0.0125
m*
K_2^b
K_2^d
K_3^b
π(2,m)
π(3,m)
π(4,m)
m
0.5
1
1.5
K
0.03
0.0275
0.025
0.0225
0.02
0.0175
0.015
0.0125
K_2^b
K_2^d
K_3^b
m*
m
0.2
0.4
0.6
0.8
1
1.2
1.4

Figure 1