NETWORK COMPETITION AND ENTRY DETERRENCE*

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We develop a model of logit demand that extends the traditional duopoly framework of network competition to a multi-firm industry. First, we show that incumbents establish the reciprocal access charge inefficiently below cost when they compete in prices but they behave efficiently if they compete in utilities. Secondly, we study how incumbents determine the industry-wide access charge under the threat of entry. We show that 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 the access charge upwards.

The telecommunications sector has been liberalised almost everywhere in the world. In spite of this, regulation remains, though the emphasis has been shifted from direct control of end-user prices to market supervision intended to guarantee the development of competition. In this pursuit, the regulation of interconnection charges is a key instrument. Telecommunications operators interconnect their networks to provide consumers with benefits from network externalities. Despite vigorous competition in the market, each operator is a monopolist over its subscribers' access lines. When a customer belonging to one network calls a subscriber of another network, only this second network is able to terminate the call. The same situation arises when the call is reversed, making interconnection a 'two-way' access problem.[1] Because this need to have a competitor terminate calls is reciprocal, regulatory authorities have not traditionally viewed this termination bottleneck with great concern. Most countries make interconnection mandatory but allow operators to determine identical reciprocal access charges bilaterally. The requirement of reciprocity has been introduced to avoid the possibility of operators establishing a double mark-up. This article shows that this approach might not always be enough to prevent anti-competitive strategies. We draw 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 entry, they may negotiate a higher reciprocal access charge to deter entry.

Recent literature has investigated the potentially collusive role of access (wholesale) charges in raising consumer (retail) prices. The seminal works of Armstrong (1998), and Laffont *et al.* (1998*a,b*) (henceforth ALRT) show that firms can use above-cost access charges as a mechanism to obtain higher profits when firms compete in linear retail prices. However, this collusive result is not robust under more sophisticated pricing strategies. ALRT demonstrate that, with two-part retail prices, the access charge

[1] For a complete review of the literature on access charges see Laffont and Tirole (2000), Armstrong (2002), Vogelsang (2003) and Peitz *et al.* (2004).

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 use price discrimination between on-net and off-net calls the profit neutrality of access charges no longer holds. Firms can soften price competition and obtain higher profits by establishing access charges *below* cost. Valletti and Cambini (2005) introduce investments in the ALRT framework and show that firms are keen to set above cost access charges in order to weaken competition over investments. Jeon *et al.* (2004) and Berger (2004) study access charges in the presence of call externalities.

One common feature of all these papers is that each considers only a single market structure: almost invariably a duopoly.[2] The objective of this article is to relax this assumption in order to assess 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 has lowered entry barriers. In cellular telephony, there are constraints that limit the availability of electromagnetic spectrum but entry is made possible by improvements in the use of frequencies and releases of additional chunks of spectrum. Countries such as Australia, New Zealand, the US and the UK are liberalising the spectrum market, e.g., by introducing 'spectrum trading' which allows, say, a broadcaster to use its frequencies to supply mobile telephony services. The emergence of mobile virtual network operators (MVNOs) in most European countries and in the US provides an additional opportunity for entry even for operators that do not own licensed spectrum.

We analyse the case where incumbent networks negotiate reciprocal access charges that are valid industry-wide, i.e., they apply to all competing firms, both incumbents and entrants. This assumption reflects the present regulation of the European Commission and the Federal Communications Commission in the US, both of which require non-discriminatory access charges. We develop a model with network-based price discrimination where profits are not neutral with respect to access charges. Incumbents recognise that the level negotiated for access charges affects *ex post* profitability and thus the attractiveness of entry *ex ante*. We identify the circumstances when incumbents want to distort the access charges away from the efficient level in order to deter entry of potential rivals.

A motivating example An interesting case study of the problem we examine here can be found in the recent history of the Turkish mobile industry.[3] From 1998 to 2001 Turkey experienced a GSM duopoly with two incumbents, called Turkcell and Telsim. In 1998, the incumbents quickly reached an interconnection agreement. Access charges for mobile-to-mobile calls were set at around 1.5 eurocents/min. These access charges between the incumbents remained unchanged until March 2001, just before the Turkish government issued two new licences. The first licence was awarded to Aria

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[2] Jeon and Hurkens (forthcoming) is the only exception we are aware of. They consider a general model with many networks but their interest is very different from ours. They focus on non-reciprocal access charges that are set by a regulator instead of reciprocal and negotiated access charges, generalising the Efficient Component Pricing Rule. They also do not consider the possibility of entry.

[3] This example is described in full by Atiyas and Dogan (2007).

(owned by a consortium of Is, a Turkish commercial bank, and TIM, the mobile phone arm of Telecom Italia) and the second one to Aycell, owned by the incumbent fixed-line operator, Turk Telekom. The new interconnection agreement, which was to be applied to all operators, increased the terminating charges to 20 eurocents/min. Aria and Aycell, who still needed to invest in network rollout, struggled and in 2003 they merged to form Avea. Thus the industry structure that was supposed to comprise four operators was reduced to three. Only then did the industry regulator obtain the power to intervene directly in interconnection and issue an 'Ordinance on Access and Interconnection'. In October 2003, the regulator negotiated the access rates at about 12 eurocents/min, further reduced to 8 eurocents/min in February 2006. Turkey remains one of the most concentrated markets in Europe and analysts do not predict further entry in the short term. In summary, in Turkey there had been a pattern of very low access charges in the duopoly period with a stable market structure, followed by a very sharp increase in the common non-discriminatory charge just before entrants started to invest. As a possible consequence of this increase, fewer entrants than anticipated decided to enter. The access charge then went down again, although only in response to negotiations with the Turkish regulator. It is this relationship between access charges and entry that our model looks at.[4]

Contribution to the Literature This article contributes to the literature in three ways. First, we show the specific impact of entry on the negotiation of access charges by incumbents. This has not been studied before in the literature on 'two-way' access pricing. We characterise how incumbents set industry-wide access charges when they face entrants. The incumbents can distort the reciprocal access charge away from the *ex post* (i.e. after entry has occurred) profit maximising level in order to reduce the attractiveness of entry. We show that, when incumbents find it worthwhile to deter entry, they naturally distort the access mark-up upwards. 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 that of Gans and King (2001) and has important implications in terms of regulatory policy.

Our second and more general contribution is to show, in an entry-deterrence game, that apparently innocuous terms applied uniformly to all industry players can be used by incumbents to manage industry structure to maximise their profits (subject of course to technological constraints on entry). In particular, we find that the uniform access charges established by the incumbents determine the number of firms that enter the market. At a given fixed cost of entry, incumbents may decide to accommodate entry, or to accommodate only a subset of entrants and deter the others. We also find that successful deterrence does not depend upon industrial concentration in the manner which one might expect, as incumbents may find it profitable to set an access charge that permits the entry of a whole group of entrants. This result provides an explanatory mechanism for the observation of Bernheim (1984) that 'the stable sizes of an industry (i.e., levels of concentration at

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[4] We note that the regulated termination rates in the later years of the Turkish experience are also mixed with the regulation of fixed-to-mobile calls that we do not analyse in our model.

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.

The third contribution of the article is to extend the traditional duopoly framework introduced by ALRT to allow the analysis of a multi-firm industry. This extension allows us to analyse the entry game. We 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 the incumbent and the other an entrant. With a single incumbent operator there is little 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. In order to consider this oligopolistic interaction we employ a model with logit demand.[5] One advantage of the logit formulation is that each network competes simultaneously with all other networks and not only with its immediate neighbours. This property is useful analytically in our multi-firm setting, making the study very tractable. We study 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 used in the literature on access charges, extended to the Salop circular city model.[6] When firms compete in prices our findings generalise to the multi-firm case, the conclusion 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 price. In this case, incumbents in a multi-firm industry have an incentive to set access charge at cost when they do not face the threat of entry.

The reason for studying both kinds of strategic interaction among firms is two-fold. First, the 'trick' of using competition in utilities instead of prices is often employed in the duopoly framework of ALRT and, more generally, 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

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

[6] We have also studied 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 fixing the number N to specific values. In both cases, the results obtained are the same as those obtained under the logit formulation, which allows a more general treatment under both kinds of strategic interaction.

induced by off-net price discrimination. We show how competition in utilities and in prices yield different outcomes as long as access prices differ from costs. In particular, when access prices are below (above) cost, then competition in prices yields higher (lower) profits than competition in utilities. Secondly, because competition in utilities results in simpler expressions in the general case, we adopt it to simplify exposition when we deal with the entry game.

The remainder of the article is organised as follows. Section 1 analyses 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 2 considers the negotiation of access charges when there is the possibility of entry. Section 3 argues that our main results on entry deterrence are robust in the face of biased calling patterns, where customers call some specific users more often ('friends & family'). Section 4 discusses our main conclusions.

1. Negotiation of Access Charges in a Multi-firm Industry

We analyse the negotiation of reciprocal interconnection charges by a group of unregulated telecommunications operators that do not face the threat of entry. First, we consider the case where firms compete with discriminatory call prices and fixed subscription fees and afterwards we present the same model with firms competing 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 access 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.* (1998*b*) we write the access 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 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. This 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. As a result, 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

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

where σ is a positive constant, which is positively related to the degree of product differentiation. It can be shown that when $\sigma \to 0$ the variance of τ_i also tends to zero. In this case, the multinomial logit reduces to a deterministic model. By contrast, when $\sigma \to \infty$, 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 cooperatively a common reciprocal mark-up m for access. 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.

1.1. *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 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.[7] 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

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[7] If, on the contrary, firms offered call prices different from perceived marginal cost, they could always make greater 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 that considers 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 (2006) for related results in models with logit demands.

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

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 (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,

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

Solving the first order condition we obtain in a symmetric equilibrium

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

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

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

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.[8]

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 (4) in the profit function (3) yields

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

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

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

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[8] 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.

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

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

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

$$\pi_i = \frac{\sigma}{N-1} \qquad (7)$$

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

This Proposition generalises 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 relatively more of their calls will be cheaper off-net calls. When this happens, firms are less interested in building market share. As a result of the negative mark-up, price competition is decreased 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 summarised 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 characterise 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 access charge.[9]

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 smaller the number of competing firms.*

Proof. The optimal mark-up is determined by (6).

(i) Take the case of low c ($c \to 0$). We can characterise the asymptotic behaviour of (6) by concentrating only on the higher-order terms. In this case (6) simplifies to

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

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

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[9] We do not allow for negative access charges, i.e., $t < 0$ is ruled out. See Section 2 below for a discussion.

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

$$\frac{\partial \pi_i}{\partial m}\Big|_{\varepsilon \to 0} = \frac{-cq}{N^2(N-1)},$$

which is always negative for any value of m. Therefore operators negotiate the lowest possible access charge, i.e., they agree on 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 (6) exists (i.e., m is negative but not as low as a 'bill-and-keep' system), the optimal m is given by:

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

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 if we took into account transaction costs, for instance, 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 that could be realised if the access charge were 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 somehow correct and firms set efficient access charges if they compete in utilities instead of prices. Section 2 confirms the regulators' concern about 'too high' access charges when incumbents are challenged by potential entrants.

1.2. *Competition in Utilities*

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

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

As explained in the introduction, our interest in analysing competition in utilities is two-fold. Firstly, we want to compare competition in prices and in utilities 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, we want to determine how they differ. Secondly, modelling competition in utilities delivers simpler expressions than competition in prices and this facilitates the analysis of the entry game studied in Section 2.

Consider the profit function in (3). After substitution of the market shares α_i and α_j as defined by (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

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

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:

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

When $N = 2$ the subscription fee simplifies to $F_i = f + 2\sigma - \{v(c) - v[c(1+m)]\}/2$, thus the access charge only affects the off-net traffic (via the off-net calling price) but not the net utility w_i. The intuition is that any losses or gains in consumer surplus due to above or below marginal cost pricing for off-net calls are fully compensated for by the firms through the adjustment of the subscription fee. However, (8) shows that the neutrality of the mark-up m on the net utility w_i does not generalise for $N > 2$. In fact, we next demonstrate 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 $v(c) > v[c(1+m)]$. Therefore, with a positive mark-up the last term in (9) is negative overall and the subscription fee decreases. 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

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

where the strict inequality stems from the fact that Δ represents the classic 'deadweight loss' when prices differ from marginal costs.[10] Similarly, it can be shown that if $m < 0$ the subscription fee increases but, overall, net utility decreases.

We are now in 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, $m = 0$.*

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[10] To confirm that Δ, as expressed by (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.

Proof. Simplifying the profit function in (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 the deadweight loss Δ, defined as in (10), is minimised for $m = 0$. We can therefore conclude that, for any number N of incumbents, $m = 0$ is the unique solution that maximises profits.

In order to understand this Proposition,[11] note that, when the incumbents set a positive access mark-up, two effects arise. The mark-up has a positive direct effect on profits as it generates access revenues. However, these access revenues are dissipated by a negative indirect effect: competition forces the firms to grant utility to consumers by 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 an increase in fixed fees because consumers pay less for off-net calls but the reduction in access revenues 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 zero. The 'perceived' marginal cost for off-net calls then coincides with the true economic marginal cost, and off-net and on-net prices both induce an efficient number of 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 achieve efficiency.

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

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

PROPOSITION 3
  (*i*) *If the access charges are exogenously set at $m = 0$, competition in prices and competition in utilities yield the same equilibrium profits. If $m < 0$ ($m > 0$), competition in prices yields strictly higher (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 (5), while (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 $m < 0$ ($m > 0$).

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

(*ii*) When m is endogenous, firms choose different mark-ups under the two kinds of strategic interaction. Firms choose $m = 0$ when they compete in utilities, 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

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

The results of Proposition 3 are 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, by setting $m = 0$ the regulator can remove calling externalities that would otherwise exist because $m \neq 0$ creates differences between on-net and off-net prices.

With competition in prices, firms prefer $m < 0$ because in this case customers want to belong to a relatively smaller network and this is a way to soften price competition and extract higher fixed subscription fees from customers. Under utility competition, if $m < 0$ firms have to compensate for the reduction of off-net revenues with an increase in the subscription fee but this increase does not balance the decrease of access revenues and therefore firms make lower profits than under price competition. 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*) of Proposition 3).

In addition, the Proposition shows that, when incumbents choose the common access 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*) of Proposition 3). Under competition in utilities firms do not want to introduce externalities by distorting the access mark-up, otherwise they would have to compensate their customers. This differs from competition in prices where externalities can be introduced via negative mark-ups to soften competition.

2. Zero Mark-ups or Entry Deterrence?

The previous Section has shown that competing incumbent networks that do not face potential entrants choose access charges either at or below cost. The particular value for the access charge depends on the type of strategic interaction among operators. While these findings have an impact on efficiency, in our model above cost access charges turn out never to be chosen, 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.[12] Introducing the possibility of entry into our model would pose little challenge if an incumbent monopolist or a group of incumbents could discriminate by setting very high access rates selectively on calls originated by entrants. In such a case, since the incumbents expect to lose from any increase in the number of competitors, they will discriminate against entrants and possibly foreclose entry.

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[12] In the US, the 1996 Telecommunications Act establishes that the access charges should be non-discriminatory. The EU establishes the same principle in the Access Directive 2002/19/EC.

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 an efficient (i.e., industry profit maximising) mark-up along the lines described in the previous Section, they maximise profits *ex post* for a given number of firms. However, this makes entry more appealing *ex ante*, thus potentially attracting too many entrants and reducing profits. Faced with this threat, incumbents may want to distort the mark-up away from efficiency in order to limit 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 to produce an impact on entry, which is the correct benchmark given our interest in entry deterrence. If entrants were asymmetrically placed, there could be additional reasons to try to affect the terms of interconnection (Carter and Wright, 2003).

To analyse how incumbents negotiate the industry access charge *ex ante* we consider the following four-stage game. At stage one, incumbent networks establish an interconnection arrangement that is valid for all industry participants and commit to not modifying it if entry occurs.[13] At stage two, entrants decide whether or not to enter the industry. If they enter, they pay a fixed entry cost K, which is the same for each. This cost is only paid by actual entrants and not by the incumbents (they may have already sunk it). At stage three and four, all operators (incumbents and actual entrants) compete against each other and customers subscribe in the way described in the previous Section.

The crucial assumption in this sequence is that incumbents are committed to (non-discriminatory) pre-entry access prices following any possible entry. While the non-discriminatory feature has already been discussed, we notice here that the possibility of setting the access charge strategically to deter entry is based on the commitment to maintain the access charge once entry has occurred. This assumption creates an opportunity for a strategic behaviour. We justify it by noting that:

(*a*) in practice interconnection deals are changed very rarely – the Turkish example discussed in the Introduction is a case in point;

(*b*) commitment can be sustained through regulatory environments where telecommunications operators typically offer binding access undertakings and so cannot easily change them *ex post*.

We solve the game backwards. Stages three and four are identical to the games examined in Section 1. At stage three all operators (incumbents and actual entrants) compete against each other and at stage four customers subscribe to one network. The equilibrium profits in stage 1 are given by (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 access mark-up, m. Thus the stage-3 equilibrium profit per firm can be written as $\pi(N,m)$. Now consider a potential

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

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 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 factors being 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 maximised 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 1 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 1 satisfy it, although parameter restrictions would be required.[14]

From now on, we concentrate on the game when the strategic variable is net utilities since it generates simpler results but the arguments laid out below also apply when firms compete in prices.[15]

Before studying the general case, we will illustrate 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, and the two incumbents will continue with the optimal $m(0) = 0$. In particular, the entrant cannot hope to recover its fixed cost when this is higher than $K_2^b \equiv \pi(3, m(0))$. 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 value that maximises *ex post* profitability. In other words, the industry is a 'non-contestable natural duopoly' and the two incumbents will not distort the mark-up.

When $K < K_2^b$ the incumbents decide to modify the mark-up m. If the incumbents keep charging the efficient mark-up $m(0) = 0$, they will trigger entry of a third firm and the incumbents' profits will suddenly decline 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 access 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. The

[14] From (11), when firms compete in utilities, it is immediately evident 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.

[15] 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).

incumbents increase the mark-up until the gross (*ex post*) profit of the potential entrant under the distorted mark-up $m(1)$ is equal to the entrant's entry cost, i.e., the mark up $m(1)$ satisfies $\pi[3,m(1)]=K$. Having deterred the first possible entrant, the incumbents earn $\pi[2,m(1)] > \pi[3,m(0)]$. This 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 strategic manipulation of the mark-up the industry would be a 'natural triopoly'. Instead, incumbents distort the access mark-up and deter entry.

When the entry cost is lower than K_2^b the incumbents need to distort the mark-up in order 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, allow 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 $K_2^d \equiv \pi(3, m^*)$. Thus, for all values of $K > K_2^d$, entry is deterred.

For $K < K_2^d$ there are two possible scenarios. The first scenario is the case when $K_2^d > K_3^b \equiv \pi[4, m(0)]$. 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) is blockaded because it cannot recover its fixed cost.

The second scenario occurs when $K < K_2^d < K_3^b$. Now the two incumbents could accommodate the third firm and set a zero mark-up. However, this will trigger the *simultaneous entry of both the third and fourth firm*. Instead, the incumbents can do better by deterring 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 $\pi(3,m) = K$. The value of m that solves this equation is denoted by $m(2)$, as it is the limiting mark-up that deters each one of the two possible entrants individually. The incumbents, having deterred both entrants, then earn $\pi[2,m(2)] > \pi[4,m(0)]$, which is the maximum profit that can be obtained in a duopoly by distorting m.

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) When $K < K_2^d$ there are two possible scenarios:
    (3.1) 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'. 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 a fourth firm, and so on.

(3.2) If $K < K_2^d < K_3^b$ the two incumbents set $m(2) > m(1)$ and entry of both the third and the fourth firms is deterred.

Figure 1 illustrates the previous reasoning with an example where there are two incumbents and only two potential entrants that compete in utilities.[16] 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 $m(0) = 0$. In the example, it is also $K_2^d = 0.016 > K_3^b = 0.015$. 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 fourth firm is 'blockaded', thus the three effective competing firms do not distort the mark-up and set $m(0) = 0$. 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, $K < K_3^d = 0.0125$ do the incumbents give up any deterrence strategy, accommodate both entrants and set an efficient industry mark-up equal to $m(0) = 0$.

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 access charges which are difficult to enforce.[17] 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 1, when operators compete over prices, they already set negative mark-ups in the absence of entry threats, and in some cases this goes as far as a zero access charge (i.e., a 'bill-and-keep' system). In order to diminish the *ex post* profitability of entrants, operators can try to distort the optimal mark-up only upwards and not downwards. In other words, distortions away from the optimal 'collusive' charge to
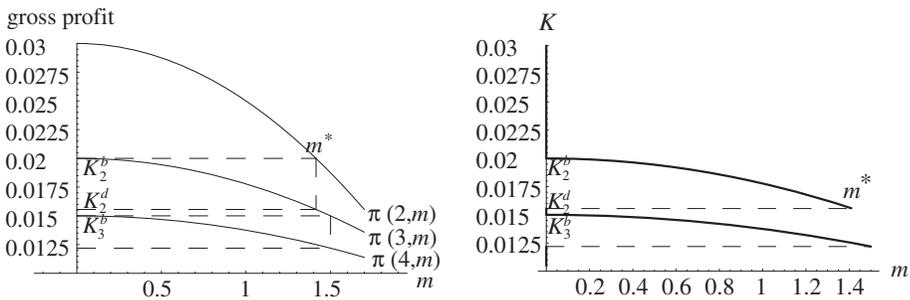

Fig. 1.   *Profits (left panel) and Mark-ups (right panel)*

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[16] We consider a linear demand function for calls $1 - p$ and a total marginal cost $c = 0.2$.

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

deter entrants are much easier and natural to implement by going to higher values of the access charge.

We complete the analysis with our final result, which illustrates how a generalised number of incumbents establish an 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., $K_{n+j}^b \equiv \pi[n + j + 1, m(0)]$, $j = 0, 1, ...$ The following Proposition describes how the n incumbents set the access mark-up and affect subsequent entry.

PROPOSITION 4 *Imagine that 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 access mark-up $m(d)$ that deters $d \leq j$ entrants, and accommodate $j - d$ entrants, where $m(d)$ satisfies:*

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

The optimal mark-up $m(d)$ is the one that maximises the incumbents' ex post individual profit:

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

and satisfies $m(0) < m(1) < ... < m(j)$.

Proof. First, note that when $K_{n+j+1}^b < K < K_{n+j}^b$ and $m(0)$, j entrants will enter while the $(j + 1)$-th entrant will be blocked. Thus, the 'natural' market structure in this range comprises $n + j$ firms. The n incumbents must decide whether to accommodate all potential entrants, just a subset, or none. If they accommodate all, then $d = 0$, 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, they must guarantee that even the first possible entrant will 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 it profitable to deter only a subset of d possible entrants and accommodate $j - d$ 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 earns 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.

3. Externalities and Calling Groups

In this Section we allow for externalities and asymmetries in calling patterns. A simplifying assumption of our model was that customers call every user randomly. However, customers usually place a greater percentage of calls to a selected number of people. For example, residential customers make most of their calls to 'friends and family' (F&F hereafter). In this situation, operators might find it profitable to push up access charges so as to make people reluctant to change networks. In fact, if all F&F belong to the same network, any single user will be very hesitant to join another

network if this means that the majority of calls to F&F are more expensive off-net calls. We next explain that this reasoning is not entirely correct. We show that without the threat of entry (or when entry is accommodated) there is no reason to distort calling patterns. In such cases, a zero mark-up is negotiated, and the presence of F&F alone is immaterial to this agreement. On the contrary, when incumbents find it optimal to deter entry, an upward distortion of the access mark-up arises once again. It turns out to be much easier to use the access mark-up to deter entry when customers find it more difficult to coordinate their F&F network with the entrant than with the incumbents. In this situation, access mark-ups can be used by incumbents to disadvantage the entrant.

To make these points formally, we extend our previous model imagining that customers have biased calling patterns. We assume that consumers make a fraction β_i of calls to their own F&F when joining network i, while the remaining fraction $1-\beta_i$ of calls is placed randomly among everybody else. In the previous Sections, we assumed that customers make all calls randomly (there were no F&F circles, i.e., $\beta_i = 0$).

We also assume that all members of the same F&F end up joining the same network and that there is no overlap between F&F groups. One could suppose that, despite the absence of any explicit coordination, people belonging to the same F&F group eventually join the same network if indeed calls end up being more expensive off-net. Alternatively, F&F groups could be seen as a proxy for social networks made of similar people with similar idiosyncratic preferences that lead them to choose the same network. This implicit coordination assumption is not necessary to obtain our results. However, it is convenient in our analysis because it eliminates pay-off dominated equilibria that are due to coordination failures.[18]

The net surplus for being subscribed to network i is

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

The first term of this equation refers to the utility from making calls to F&F. As F&F are all subscribed to the same network, all these calls are charged the on-net price. The second term refers to the rest of the calls, which are randomly distributed among all customers. These calls might be on-net or off-net. Notice that the presence of F&F does not imply that people call more. Indeed, if the same price is charged both on- and off-net, the presence of F&F does not change the total number of calls, only the distribution of those calls.

As before, firms set call prices equal to the perceived marginal costs, that is, $p_{ii} = c$ on-net and $p_{ij} = c(1 + m)$ off-net. With these prices the profit of firm i can be written as

$$\pi_i = \alpha_i(F_i - f) + (1 - \beta_i) \sum_{j=1, j \neq i}^{N} \alpha_i \alpha_j mcq[c(1 + m)].$$

Everything else is as before. We consider once again the case of competition in utilities and assume initially that all competing firms are symmetric with respect to F&F

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[18] A more detailed study of consumer behaviour with calling groups (including the choice of being a sender or a receiver) is in itself an interesting question that we must leave to further research.

($\beta_i = \beta$ for all i). It is straightforward to extend the analysis conducted in Section 1.2 and derive the fixed subscription fee in equilibrium:

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

The corresponding equilibrium profit is:

$$\pi_i(N, m) = \frac{\sigma}{N-1} + (1-\beta)\frac{\Delta}{N^2} \tag{12}$$

where Δ is given again by (10), with $\Delta < 0$ for all $m \neq 0$ and $\Delta = 0$ for $m = 0$. These expressions have the very same structure as before and, thus, we can reach the same conclusions.

If entry is accommodated, the expression for the profit is maximised for $m = 0$, and the F&F parameter, β, plays no role. If entry is to be deterred, the same deterrence mechanism described in Section 2 can be put to work. For a given mark-up, the presence of an F&F circle has an impact on profits. Since proportionally more calls are made on-net, the distortion due to the mark-up has a smaller impact on profits (in (12) Δ is now multiplied by $(1 - \beta) < 1$). For this very reason, with F&F, incumbents need a greater distortion in the mark-up to deter entry. This does not imply that it is necessarily more costly for the incumbents to deter the entrant, since the incumbents' profits are less affected by the mark-up via the β. We have thus found that no mark-up is charged when entry is either blockaded or accommodated, even in the presence of calling groups such as F&F. When entry is deterred, a distortion in the uniform access mark-up is still an effective tool, though bigger distortions are needed.

Things change quite dramatically if we introduce an asymmetry between incumbents' and entrants' F&F circles. The introduction of asymmetries generates analytical solutions that are quite cumbersome, so it is more intuitive to illustrate our results using diagrams for a simple case. Imagine there are three firms, two incumbents (denoted as 1 and 2) and one entrant (denoted as 3). We assume that F&F circles exist *only* for the incumbents and not for the entrant. Incumbents have identical F&F circles ($\beta_1 = \beta_2 = \beta$) while the entrant has no F&F circle at all ($\beta_3 = 0$). This could reflect, for example, that the entrant has had insufficient time to establish a reputation that affects calling behaviour. We do not model how reputation can be built up, as we take for granted the process that leads people belonging to the same group to coordinate implicitly on one of the incumbent networks. This is obviously quite extreme but captures the idea that an entrant has no history and this generates a potential asymmetry that we capture in a lack of coordination among potential F&F members when joining the entrant. What matters for our results is not that the entrant has no calling circle at all but simply that it has a smaller circle than the incumbents ($\beta_3 < \beta$).

Given these assumptions, it is clear that a mark-up has a greater negative effect on the entrant than on the incumbents. This is not because of idiosyncratic preferences (these are still symmetric) but due to the fact that, if a customer switches to the entrant, more calls will be off-net calls, which are expensive when there is a mark-up on the access charge. Incumbents, on the contrary, do have F&F circles and proportionally more of their calls are on-net and cheaper. Of course, when $m = 0$ both the entrant and the incumbents are again completely symmetric as F&F groups do not matter when prices are uniform.

We have solved the model and report the plot of the equilibrium (gross) profits and market shares in Figure 2. The left panel plots profits for incumbents and entrant for two different values of β. The dotted curves are drawn for $\beta = 0.2$ (the higher curve refers to the incumbents and the lower curve refers to the entrant), while the continuous curves are drawn for $\beta = 0.5$ (again, the higher curve refers to the incumbents and the lower curve refers to the entrant).

We can draw two implications, which once more emphasise the role of entry deterrence. Although the incumbents suffer less than the entrant, they still suffer from a mark-up. Therefore incumbents might prefer to accommodate entry and not impose any mark-up, notwithstanding the *ex ante* F&F asymmetry. It is better for them to accommodate entry, charging a common non-discriminatory $m = 0$, despite the fact that this choice ends up washing away the *ex ante* asymmetry!

However, a deterrence strategy is much easier to implement in these circumstances for two reasons. First, the entrant suffers seriously from any mark-up. The left panel of Figure 2 shows that the higher β is, the lower are the entrant's profits, which is the relevant payoff to be considered for deterrence. Similarly, the right panel shows that the entrant's market share diminishes as β increases. Second, the incumbents suffer less from any mark-up. This can be easily seen as the profits from successful deterrence are given by (12), which shows that the negative impact of the mark-up summarised by $\Delta < 0$ is diluted by β.

In sum, tariff-mediated network externalities, which indeed exist when firms discriminate between on and off-net traffic and may be particularly strong in the presence of F&F circles, do not change our results. If entry is accommodated, there are no strong reasons for the incumbents to distort the mark-up upwards, even if this may amount to losing any *ex ante* F&F advantages incumbents might have. Mark-ups as an entry-deterrence device are robust to the introduction of F&F. In fact, it becomes even easier to implement this strategy if F&F groups put the entrant at some disadvantage. Therefore calling externalities, alone, do not introduce a strong motive to justify access mark-ups while, when conjoined with entry deterrence, they are complementary to each other.[19]
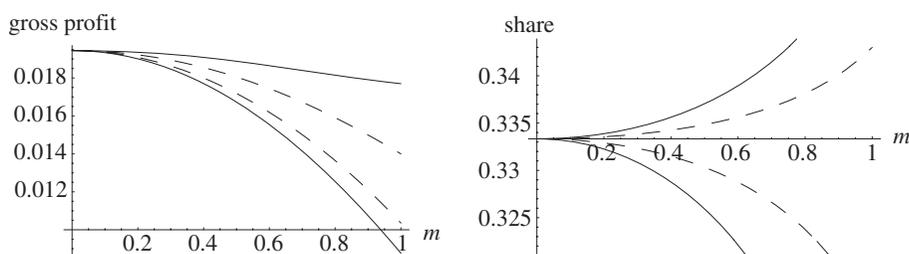

Fig. 2. *Profits (left panel) and Market shares (right panel)*

[19] F&F together with switching costs may give a reason for incumbents to charge positive markups, even in the absence of entry. If all members of a calling club are subscribing to the same network, price discrimination will tend to increase individual switching costs, and this may enable firms to charge higher fixed fees. To reach this result it is essential that some customers face very high exogenous switching costs to make other people reluctant to relocate away from those friends who are locked in. See Gabrielsen and Vagstad (2008).

4. Conclusions

Two decades after the liberalisation of most telecommunications markets, regulators are still concerned about the need to regulate access charges. High access charges can increase operators' retail prices and reduce consumers' well-being. Moreover, incumbent networks can use access charges to diminish competition in the existing market and restrain the entry of new firms. The economic literature on 'two-way' interconnection has offered ambiguous results concerning the way operators negotiate reciprocal access charges in the absence of regulation. This article has extended the traditional duopoly model that analyses the negotiation of access charges to consider the case of competition among multiple network. It has been shown that when incumbents do not face entry threats, they establish an inefficient access charge below cost if they compete in price 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 article has shown that this view can be reconciled with our model when we allow for the possibility of entry. Under entry, incumbent networks may decide to set an industry-wide (non-discriminatory) access charge that accommodates all possible entrants or only a group of them, or may decide to use the access charge to deter entry completely. The optimal strategy for the incumbents is the solution of a trade-off. They can establish the efficient mark-up that maximises 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 emphasise 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 pays 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 differ depending on whether firms compete on prices or utilities.

Notice that whenever incumbents increase the access charge above cost in order to deter entrants, they introduce allocative distortions for calls, as the off-net price is set above marginal cost. This behaviour 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 prevails 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.

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