Access Pricing under Competition: An Application to Cellular Networks*

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Abstract

A new class of access pricing problems is analyzed, in which upstream firms compete for customers and access to these customers is required by downstream markets. Using fixed-to-cellular calls as an example, a model is presented which shows that the determination of cellular termination charges is quite different to standard access pricing problems. Competition between cellular firms leads to access prices being set either at, or above, the monopoly level. Applications are given for other market settings, including the termination of long-distance calls on competing local exchange networks and the setting of interchange fees in payment systems.

1 Introduction

In the traditional theory of access pricing, an upstream firm that controls a bottleneck facility sets a price for access to the facility to extract monopoly profits from it. As a result, most bottleneck owners have their access prices regulated, typically to some measure of costs.[1] Conventional wisdom is that facilities based competition between access providers can solve the problem of inflated access prices. Firms will undercut each other in providing access to their facilities, and in so doing will lower access prices to cost.

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[1] Armstrong *et al.* [1996] provide a synthesis of access pricing theory when retail prices are regulated. Armstrong and Vickers [1998] extend the analysis to the case of deregulated retail prices.

In this paper a new class of access pricing problem is analyzed, in which it is a firm's customers that create the bottleneck. To keep the discussion concrete, the case of fixed-to-mobile phone calls is used. For a call made to a person with a cellphone, the fixed-line network (the downstream firm) requires access to the particular cellular firm to which the person being called subscribes (the upstream firm). In most countries, the fixed-line network collects the proceeds from the call, but pays the cellular firm a termination charge for completing the call.[2] This gives the cellular firms a kind of bottleneck over terminating calls. This view is taken by the United Kingdom telecommunications regulator OFTEL, who in 1997 stated:

> "Mobile network operators, like all network operators, have a monopoly position over the 'termination' of calls on their own networks. Operators have such a monopoly position because when someone wants to make a call to a mobile, or any other phone, then the calling party has no choice but to call the network to which the called party has subscribed." (OFTEL [1997], paragraph 1.2)

However, unlike a typical bottleneck access provider, cellular firms compete for the right to terminate calls by competing for mobile phone subscribers. Interestingly, this competition for subscribers need not lead to lower access pricing, and in fact can increase access prices above the monopoly level. Competition does not eliminate the rents from the access bottleneck. Rather it transfers them from the cellular firms to their customers. Above cost termination charges make cellular customers more valuable to the cellular operators, leading competing cellular firms to lower the retail prices they charge in an attempt to capture more customers. Even though competition will drive down the total amount cellular firms collect from fixed-to-mobile callers and mobile subscribers towards cost, the allocation of costs to calling and called parties will remain distorted. Fixed-to-mobile callers will end up paying the monopoly price, or more, while cellular subscribers will be heavily subsidized. In general, competition does not lead to the efficient allocation of costs between the two types of customers.

To derive results a simple model is used in which n imperfectly competitive cellular firms charge a fixed-line network for access to their customers. The model is one of two stages. In the first stage cellular firms set their termination charges. In the second stage cellular firms compete in the retail market, either in prices or quantities, and the fixed-line network sets the price of fixed-to-cellular calls.

When cellular firms change their termination charges there are two types of effects. First, a higher termination charge will increase the fixed-to-mobile price and decrease the demand for fixed-to-mobile calls. This will generally change the profits from terminating fixed-to-mobile calls to each cellular customer. Second, any increase in termination profit per subscriber will make cellular customers more valuable, causing cellular firms to compete more aggressively to capture such customers.

When the fixed-line network can set differential fixed-to-mobile prices depending on which cellular network calls terminate on, the model implies competition will lead cellular firms to set termination charges at the same level as would be set by a single monopoly cellular operator. To understand this

[2] This is based on the 'calling party pays' principle that applies in most countries; the obvious exception being the United States. The receiver pays approach used in the United States is discussed in Section 6.1).

result, note a single monopoly cellular firm will maximize profits by maximizing termination profits per subscriber. A competing cellular firm, that can determine its termination profit per subscriber by changing its termination charge, will face an additional incentive. As termination profit per subscriber increases it will increase the marginal profitability of attracting subscribers. This will make it compete more aggressively. Regardless of whether rival firms also compete more aggressively (firms compete in prices) or if this softens rivals' reactions (firms compete in quantities), firms will generally benefit from increasing their own marginal profitability. Thus, each cellular firm will maximize its own marginal profitability by maximizing its termination profit per subscriber. The result is termination charges set at the monopoly level.

When the fixed-line network sets a uniform fixed-to-mobile price, the model implies competition will lead cellular firms to set even higher termination charges. There are two reasons for this result. First, the monopoly level of access prices now increases. Due to the uniform fixed-to-mobile price, any individual cellular operator will share the decrease in fixed-to-mobile demand resulting from an increase in its access price with the other cellular operators. This implies it will want to set a higher termination charge. Second, when a cellular firm (say firm 1) increases its termination charge, the reduction in fixed-to-mobile demand reduces the termination profit per subscriber earned by rival firms. This is equivalent to rival firms facing a decrease in their marginal profitability of attracting subscribers, which makes them less aggressive in the second stage competition. This benefits firm 1, and results in it choosing even higher termination charges.

In a symmetric equilibrium, where all firms behave in this way, the result is access prices will be set above the monopoly level. In fact, in the special case of Hotelling competition, where everyone subscribes to one of two cellular firms, the model implies there will be an escalation of termination charges which in the limit will destroy the fixed-to-mobile market.

We discuss welfare implications of different fixed-to-mobile termination charges, building on the discussion in Armstrong [1997]. Armstrong analyzed the optimal regulation of termination charges set by cellular firms in a model in which the cellular sector is perfectly competitive and in which everyone subscribes to one of the cellular firms. He shows that as termination charges increase, cellular connection charges decrease. Despite this, since fixed-to-mobile prices are assumed to be set at perceived cost, efficiency requires that termination charges be set at the cost of terminating calls on the cellular networks. However, Armstrong did not consider the incentives for unregulated cellular firms to set access prices under competition.

Written contemporaneously with an earlier version of the present paper[3], Gans and King [2000] showed that competing cellular firms have a tendency to set high termination charges. Gans and King use a Hotelling model of competition between two firms, where everyone subscribes to one of the two cellular firms. They emphasized the role of consumer ignorance in this process. If fixed-to-mobile callers are not aware of which cellular network their calls terminate on, they will only consider the average

[3]See Wright [1999]. This earlier version considers the case of two cellular firms competing according to Hotelling competition with full participation, and also considers numerically the case with partial participation.

fixed-to-mobile price when determining how long to talk.

Subsequently, Armstrong [2001] has extended his 1997 note to look at the incentives facing cellular firms in setting termination charges. He finds that when the cellular market is perfectly competitive and the fixed-line network sets different prices for calls to the different cellular firms, cellular firms will set termination charges at the monopoly level.[4] Competitive cellular firms will want to maximize termination profits so as to subsidize their cellular activities as much as possible.

The approach taken in this paper generalizes the above results to a wide class of models of imperfect competition between firms, and so highlights the underlying logic that gives rise to them. The rest of the paper is structured as follows. Section 2 presents our model, which is then analyzed in the case of differential prices (Section 3), in the case of uniform prices (Section 4), and in the case in which firms set a common termination charge (Section 5). Section 6 contains a discussion of the results, in terms of some extensions of the model (Sections 6.1 and 6.2) and some welfare implications (Section 6.3), while Section 7 contains some applications to other settings. Finally, Section 8 briefly concludes with policy implications.

2 A model of access pricing to customers

The model will be described in terms of fixed-to-mobile calls. Section 7 discusses some other applications. To concentrate the analysis on the termination problem, mobile-to-mobile and mobile-to-fixed calls are initially ignored. Such calls are considered in Section 6.2.

The game is one of two stages. In the first stage, cellular firms simultaneously choose their access prices a_i for terminating calls to their subscribers. In the second stage a price for fixed-to-mobile calls to each cellular network P_i is determined, and simultaneously n cellular firms sell subscriptions to consumers and provide termination for fixed-to-mobile calls to these consumers. The model of second stage competition between cellular firms is left quite general, so that the cellular firms can compete in either prices p_i or quantities q_i. For cellular firms, the prices p_i can be interpreted as fixed charges paid by each subscriber (for example, monthly charges for a cellular package) and q_i is then the number of cellular subscribers firm i attracts. In other applications the prices and quantities may relate to usage rather than subscription.

For simplicity a single fixed-to-mobile network is assumed. As will become clear, it is straightforward to allow for more than one (symmetric) fixed-line network without affecting results. Any fixed-line network faces two types of costs for fixed-to-mobile calls. First, there is a cost C for each call originated. Second, the fixed-line network faces the termination charge a_i for each call that is required to be terminated on cellular firm i's network. The demand for calls from the fixed-line network to each cellular subscriber on firm i is given by the downward sloping demand curve $Q(P_i)$, where P_i is the fixed-to-mobile price for calling a subscriber on cellular firm i. Since there are q_i such subscribers on firm i, the fixed-line network earns profit of

$$\Pi = \sum_{i=1}^{n} q_i(P_i - C - a_i)Q(P_i). \tag{1}$$

[4] An earlier version of this paper, Wright [2000], finds the same result for a Hotelling model of competition.

Due to government regulations even a single fixed-line firm may not be able to set the monopoly price for fixed-to-mobile prices. We require that fixed-to-mobile prices, however they are set, are increasing functions of the costs faced, and do not depend on the prices p_i or quantities q_i. In particular, the best response function for P_i in the second stage game, is assumed to be able to be written as

$$P_i = f(C + a_i), \tag{2}$$

where f is assumed to be a strictly increasing function. This is obviously true in the case fixed-to-mobile prices are regulated to cost $C + a_i$. It is also true in the case a single fixed-line network is free to set the monopoly fixed-to-mobile prices, provided the number of cellular subscribers q_i does not depend on the fixed-to-mobile prices.[5]

Cellular firms incur a cost c for each subscriber they service, and d for each fixed-to-mobile call terminated. Firm i's profit consists of termination profit and retail profits, so it can be written as

$$\begin{aligned} \pi_i &= q_i(a_i - d)Q(P_i) + (p_i - c)q_i & (3) \\ &= (\pi_i^a + p_i - c)q_i, & (4) \end{aligned}$$

where $\pi_i^a = (a_i - d)Q(P_i)$ is firm i's profit from terminating calls *to each of its subscribers*. It is insightful to rewrite profits as

$$\pi_i = (p_i - c_i^a)q_i, \tag{5}$$

where $c_i^a = c - \pi_i^a$ is the net cost of terminating calls to each subscriber. In the second stage of the game, each cellular firm i sets its choice variable (either p_i or q_i) to maximize π_i given the retail price or quantity of the other cellular firms, and given the fixed-to-mobile prices. Cellular firm i's choice variable will be denoted x_i for generality.

Equation (5) shows that the profits of each cellular firm can be written in a very standard way. This suggests that with respect to second stage competition, an increase in termination profits per subscriber is equivalent to a decrease in unit cost per subscriber. As will be shown, this equivalence will indeed hold, since the unit cost c_i^a can be treated as if it is determined in the first stage by the choice of the access price a_i, and given the resulting cost c_i^a, retail prices (or quantities) are then determined through cellular competition in the second stage. The effect of a change in π_i^a on the choice of prices (or quantities), and on the firms' profits, then follows from standard comparative static results.

In particular, we will make use of the following assumptions on the second stage model of competition. An increase in unit costs c_i^a for a single firm i causes:

A1. q_i to decrease.

A2. p_i to increase.

A3. π_i to decrease

[5] Cellular demand q_i may depend on fixed-to-mobile prices if cellular subscribers obtain utility from receiving calls. This case is analyzed in Section 6.1.

A4. π_j to increase for all $j \neq i$.

While none of these assumptions are controversial, they do not necessarily hold for every possible model of oligopoly. However, the assumptions do follow for some reasonably general classes of oligopoly models. (A1) and (A4) have been shown by Dixit [1986] to follow from second-order conditions and stability conditions for a duopoly (either Bertrand or Cournot, with either homogeneous or heterogeneous products). Dixit also shows (A1) and (A4) follow for an n-firm Cournot oligopoly, either one with no product heterogeneity, or with symmetric product heterogeneity in the sense firm i's price depends only on its own output and the average output of its $n-1$ rivals. It is straightforward to show (A2) follows given standard stability conditions for a duopoly. More generally, (A2) follows for an n-firm differentiated Bertrand oligopoly from standard results in monotone comparative statics (see Milgrom and Roberts [1990]). For an n-firm Cournot model with no product heterogeneity, (A2) follows from the result in Dixit that industry output decreases when firm i's unit cost increases.

To ensure (A3) holds requires placing some additional restrictions on the permissible class of oligopoly models, since it is possible that an increase in a firm's unit cost may actually increase its profit if it leads rival firms to increase their prices sufficiently. We are assuming away such perverse cases. Fincham [2001] shows that for an n-firm differentiated Bertrand model in which each firm's demand can be written

$$q_i = A - \alpha p_i + \frac{\beta}{n-1} \sum_{j \neq i} p_j, \tag{6}$$

a sufficient condition for assumption (A3) to hold is that the own price effect is at least as strong as the cross price effect; that is, $\alpha \geq \beta$. This clearly covers the case of a standard duopoly with linear demand.

The case also covers the standard Hotelling model of product differentiation, which itself is a special case of a duopoly with a linear demand function in which $\alpha = \beta$. To see this note that if there are two firms and p_i represents subscription charges, then q_i can be interpreted as the market share arising from a standard Hotelling model. In particular, where the two firms are located at extremes of a unit interval and uniformly distributed consumers face linear transportation cost tx for travelling a distance x, then firm 1's 'demand' function is its market share, that is

$$q_1 = \frac{1}{2} + \frac{p_2 - p_1}{2t} \tag{7}$$

and firm 2's 'demand' function is $1 - q_1$.[6]

In addition to these assumptions, for Section 5 we will make use of the following alternative set of assumptions. An equal increase in unit costs c_i^a for all firms will cause:

A5. q_i to decrease for all i.

A6. p_i to increase for all i.

A7. π_i to decrease for all i.

[6] Assumption (A3) also holds for the simple extension of this Hotelling model to n-firms, where the firms are located at vertices on an n-dimensional simplex and consumers are uniformly located along the line segments joining the vertices. In this case $A = 1/n$, $\alpha = 1/nt$ and $\beta = 1/nt$ in (6).

A7$'$. π_i to remain constant for all i.

Assumptions (A5) and (A6) are natural extensions of (A1) and (A2) to the case in which all firms face an equal increase in unit costs. In the case of a standard n-firm Cournot model with product homogeneity, (A5) and (A6) follow from symmetry and the fact the industry output must decrease (see Dixit [1986]), so that all firms face higher prices. Appendix A of Schmalensee [2001] shows (A5) and (A6) also hold for a model of n-firm differentiated Bertrand competition with symmetric product heterogeneity, where symmetry is in the form given by (6). It follows that (A5) and (A6) also hold for a Bertrand duopoly with linear demands.

Seade [1985] provides conditions under which (A7) holds for the case of an oligopoly. He shows that an equal increase in unit costs for all firms does not necessarily lower the profitability of all firms in the industry, but will do so provided the inverse demand function depends only on aggregate output, and the elasticity of the slope of the inverse demand function is less than two. In addition, he suggests that it should be possible to obtain similar results if the inverse demand function depends on own and aggregate residual output. Fincham [2001] shows that for demand functions of the form (6), assumptions (A5)-(A7) hold provided the own price effect is stronger than the cross price effect; that is, $\alpha > \beta$. We also allow for the possibility of (A7$'$), that an equal increase in costs leaves the profits of all firms unchanged, as is the case with the Hotelling model of competition. Assumption (A7$'$) applies whenever the own price and cross price effects are of equal magnitude in (6).

3 Differential fixed-to-mobile pricing

In this section it is assumed fixed-line networks can set their fixed-to-mobile prices differentially depending on the termination charge each cellular firm sets. It is useful to start by considering the access price set by a cellular firm that has a monopoly in the cellular market. Not only does this case provide a benchmark for cases in which cellular firms compete, but it illustrates how the access pricing problem can be rewritten in a way that turns out to be more tractable.

A monopoly cellular firm faces a direct and two indirect effects when setting its termination charge. Based on (3), the total impact on π_i of a change in a_i is

$$\begin{aligned} \frac{d\pi_i}{da_i} &= \frac{\partial \pi_i}{\partial a_i} + \frac{\partial \pi_i}{\partial P_i}\frac{dP_i}{da_i} + \frac{\partial \pi_i}{\partial x_i}\frac{dx_i}{da_i} \\ &= q_i Q(P_i) + q_i(a_i - d)Q^{'}(P_i)f' \end{aligned} \tag{8}$$

An increase in a_i increases the margin from terminating each call to its cellular subscribers. This is a direct positive effect on firm i's profits, and is represented by the first term in (8). An indirect effect also arises, in which the increase in the termination charge in the first stage increases the fixed-line network's optimal fixed-to-mobile price in the second stage of the game. This increase in P_i will decrease demand for fixed-to-mobile calls, which decreases the profit obtained from setting the termination charge above cost. This is the second term in (8). The third term in (8) arises because the cellular monopolist will want to change its own price (or quantity) as a result of the increase in a_i. However, since it already sets its own price (or quantity) to maximize profit, by the envelope theorem this will have no effect on its profit at the margin. Thus, a monopolist will maximize termination profits per subscriber by trading off the higher margins resulting from a higher a_i with the lower demand for fixed-to-mobile calls.

The monopolist's access pricing problem can be transformed to a more useful form by noting that π_i^a is determined independently of the cellular firm's choice of x_i in the second stage. This is because a_i is chosen in the first stage of the game and P_i, although chosen in the second stage, is independent of x_i. Hence, the cellular firm can treat π_i^a as if it is determined prior to the setting of its own retail price (or quantity). In other words, as the cellular firm changes a_i it will determine π_i^a (allowing for the change in P_i by the fixed-line network), as if this change in π_i^a occurs in the stage prior to the setting of retail prices (or quantities). This implies (8) can be rewritten as

$$\begin{aligned}\frac{d\pi_i}{da_i} &= \frac{\partial \pi_i}{\partial \pi_i^a}\frac{d\pi_i^a}{da_i} + \frac{\partial \pi_i}{\partial x_i}\frac{dx_i}{d\pi_i^a}\frac{d\pi_i^a}{da_i} \\ &= q_i\left[Q(P_i) + (a_i - d)Q^{'}(P_i)f'\right]\end{aligned}$$

where $\partial\pi_i/\partial x_i = 0$ by the envelope theorem. As will be shown below, this same logic applies to the more general case in which cellular firms compete in the second stage.

The monopoly level of the access price in the case of differential pricing, a^D, then solves the first-order condition

$$\frac{d\pi_i^a}{da_i} = Q(P_i) + (a_i - d)Q^{'}(P_i)f' = 0, \tag{9}$$

which implies[7]

$$a^D = d - \frac{Q(P_i)}{Q'(P_i)f'} > d. \tag{10}$$

The termination profit per cellular subscriber evaluated at the monopoly access price a^D is then defined as π^D.

Even with second stage competition, cellular firms will continue to want to maximize termination profits per subscriber, since as (5) shows, this is equivalent to a decrease in one's own unit cost. Provided the strategic effect of decreasing ones own unit cost (in terms of increased second stage competition) does not offset the direct benefits of higher marginal profitability, the monopoly result will continue to hold. Proposition 1 formalizes this result.

Proposition 1 *Given (A3) and differential fixed-to-mobile prices, each cellular firm will set its access prices at the monopoly level a^D.*

Proof. The total impact of a change in a_i on cellular profits can be determined using the fact that the effect of a change in a_i on π_i^a can be determined independently of the choice variable x_i in the second stage. Since the best response function (2) is determined without reference to the choice variables x_1, ... , x_n, it is possible to first determine how a change in a_i will affect termination profits per subscriber π_i^a as if this occurs in the first stage of the game. The resulting change in π_i^a will then cause a change in the second stage choice variables.

[7]We assume second order conditions apply.

Considering the profit functions in the form (5), and taking into account the envelope theorem, the total impact of a change in a_i on cellular profits is then simply the impact of a change in a_i on termination profits per subscriber multiplied by how a decrease in a firm's own cost affects its profits

$$\begin{aligned}\frac{d\pi_i}{da_i} &= \frac{\partial \pi_i}{\partial \pi_i^a}\frac{d\pi_i^a}{da_i} + \sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\frac{dx_j}{d\pi_i^a}\frac{d\pi_i^a}{da_i} \\ &= -\left[\frac{\partial \pi_i}{\partial c_i^a} + \sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\frac{dx_j}{dc_i^a}\right]\frac{d\pi_i^a}{da_i} \qquad (11)\end{aligned}$$

Given (A3) the expression in the square bracket will always be negative. Thus, $d\pi_i/da_i$ has always the same sign as $d\pi_i^a/da_i$, and each cellular firm's profit π_i will be maximized by maximizing π_i^a. From (9) this is achieved by setting $a_i = a^D$. ■

The above proposition can be interpreted in the case two firms compete in prices. When a cellular firm increases its termination charge, so as to increase termination profits per subscriber, this makes cellular customers more valuable to the cellular operator, leading it to decrease its retail price in an attempt to capture more such customers. Since an increase in termination profits per subscriber is equivalent to a decrease in unit costs, this result follows from the assumption (A2), which implies that a decrease in unit costs will lead a firm to decrease its price.

The derivative in (11) can be rewritten

$$\frac{d\pi_i}{da_i} = \left[q_i - (p_i - c_i^a)\frac{\partial q_i}{\partial p_j}\frac{dp_j}{dc_i^a}\right]\frac{d\pi_i^a}{da_i} \qquad (12)$$

Provided prices are strategic complements, the rival cellular firm will also decrease its cellular price. Since a small change in firm i's price will not affect its profits (its price is already set to maximize profits), the only feedback effect on profits is from the decrease in firm j's price. This will decrease the number of subscribers that firm i has, which, in turn, will decrease firm i's profits to the extent firm i earns a positive margin on each subscriber.

Note that, if firms earn no margin, so $p_i = c_i^a$, (12) can be simplified to

$$\frac{d\pi_i}{da_i} = q_i\frac{d\pi_i^a}{da_i}. \qquad (13)$$

In this case, a change in the firm's number of subscribers due to a change in its rival's price will have no effect on the firm's profit. Thus, the strategic effect does not exist, and only the direct effect remains. Each cellular firm will simply set termination charges at the monopoly level a^D. This is consistent with the result found by Armstrong [2001], that with perfect competition and differential fixed-to-mobile prices, cellular firms will set the monopoly termination charge.

With imperfect competition firms will earn positive margins in the second stage. Using $\partial\pi_i/\partial p_i = 0$, (12) can be rewritten as

$$\frac{d\pi_i}{da_i} = q_i\left[1 + \frac{\frac{\partial q_i}{\partial p_j}}{\frac{\partial q_i}{\partial p_i}}\frac{dp_j}{dc_i^a}\right]\frac{d\pi_i^a}{da_i}. \qquad (14)$$

Equation (14) shows why under normal conditions (A3) holds for a price setting duopoly. The direct effect of a one dollar decrease in unit costs is to increase unit profits by one dollar. This is the first term in the square brackets in (14). Generally, the decrease in profits from the strategic effect is less than one dollar. This is true for two reasons. First, firm j will likely decrease its price by less than one dollar (in magnitude). Even if firm i decreases its own price by more than one-for-one with the decrease in its unit cost, firm j's price change will be only a fraction of that of firm i. Second, even if the rival firm did lower its price by one dollar, this will have a smaller impact on firm i's demand than the same decrease in firm i's price whenever the own demand effect is stronger than the cross demand effect. These properties suggests that typically the second term in the square brackets in (14) will be greater than minus one, so that the term in square brackets is always positive. Hence, the optimal access price is determined by $d\pi_i^a/da_i = 0$, just as in (13).

When firms compete in quantities according to the standard Cournot model, the result holds even more generally. If a firm increases its marginal profitability by increasing termination profits per subscriber, this will increase its own output (A1), and so decrease the output of its rivals (if quantities are strategic substitutes). Since a decrease in the output of rival firms increases one's own profit, the strategic effect reinforces the direct effect. Thus, firms will still seek to maximize their termination profit per subscriber by setting the access price at the monopoly level.

These results can be illustrated in the case of the standard Hotelling market share function (7). Firm i's equilibrium price is

$$p_i = c + t - \frac{2}{3}\pi_i^a - \frac{1}{3}\pi_j^a.$$

Note both firms' prices decrease less than one-for-one with an increase in their, or their rival's, termination profit per subscriber. For given termination profits, the equilibrium profit for cellular firm i is

$$\pi_i = \frac{1}{2t}\left(t + \frac{1}{3}\left(\pi_i^a - \pi_j^a\right)\right)^2.$$

Clearly to maximize profits, each firm will want to set its termination charge at the level which maximizes its termination profit per subscriber. In equilibrium, $\pi_i^a = \pi_j^a = \pi^D$, and the profits of cellular firms are just equal to the usual Hotelling level $\pi_i = t/2$. Although, in equilibrium, cellular firms do not obtain higher profits as a result of terminating fixed-to-mobile calls, competition does not eliminate the rents from the access bottleneck. Rather it transfers them from the cellular firms to their customers. Note that the equilibrium prices facing cellular subscribers are $p_i = c + t - \pi^D$, while the fixed-to-mobile price will be $P = f(C + a^D)$.

4 Uniform fixed-to-mobile pricing

In this section the case in which the fixed-line network sets a uniform price is examined. This could arise as a result of regulation, as a result of the numbering system not distinguishing different cellular networks, or as a result of the fixed-line network choosing to keep its pricing structure simple. Alternatively, this could capture the idea of Gans and King [2000], that fixed-to-mobile callers are not aware of which cellular network their calls terminate on, and so will only consider the average fixed-to-mobile price when determining how long to talk.

With uniform pricing, the fixed-to-mobile price is denoted P. The fixed-line network's profit in (1) can then be written as

$$\Pi = \sum_{i=1}^{n} q_i \left(P - C - \sum_{i=1}^{n} s_i a_i \right) Q(P), \tag{15}$$

where

$$s_i = \frac{q_i}{\sum_{i=1}^{n} q_i}$$

is the market share of firm i. The assumption that fixed-to-mobile prices in the second stage of the game are set based only on perceived cost is maintained, so

$$P = f\left(C + \sum_{i=1}^{n} s_i a_i \right), \tag{16}$$

where f is the same strictly increasing function as before.

Solving the problem for the termination charge set by a monopoly cellular firm first (that is, treating cellular market shares as fixed), turns out to be instructive. Since with fixed market shares, π_i^a is determined independently of the cellular firm's choice of x_i in the second stage, the cellular firm can again treat π_i^a as being determined prior to the setting of its own retail price (or quantity). This implies

$$\begin{aligned} \frac{d\pi_i}{da_i} &= \frac{\partial \pi_i}{\partial \pi_i^a} \frac{d\pi_i^a}{da_i} + \frac{\partial \pi_i}{\partial x_i} \frac{dx_i}{d\pi_i^a} \frac{d\pi_i^a}{da_i} \\ &= q_i \left[Q(P) + (a_i - d) Q^{'}(P) f' s_i \right], \end{aligned}$$

where $\pi_i^a = (a_i - d)Q(P)$ and $\partial \pi_i / \partial x_i = 0$ by the envelope theorem. The only difference between this case and that under differential pricing is that in this case an increase in any individual cellular firm's termination charge will have only a small effect on the fixed-to-mobile price, since prices are set based on the average of all the cellular firms' termination charges.

The monopoly access price under uniform pricing, a_i^U, solves

$$\frac{d\pi_i^a}{da_i} = Q + (a_i - d) Q^{'} f' s_i = 0. \tag{17}$$

This implies the monopoly access price under uniform pricing is higher than under differential pricing. In fact,

$$a_i^U = d - \frac{Q(P)}{Q'(P) f' s_i} > a^D. \tag{18}$$

The smaller is firm i's market share, the smaller will be the reduction in fixed-to-mobile demand when it increases its access price. Essentially, firm i is able to share the burden of its higher access prices across all fixed-to-mobile calls. The smaller is its market share, the more it can exploit this fact by setting a higher access price.[8]

In addition to the increase in the monopoly access price under uniform prices, competition for mobile customers introduces an additional strategic effect which also increases the optimal access price when a uniform fixed-to-mobile price is set. This arises from the fact when firm i increases its access price, this will decrease the demand for all fixed-to-mobile calls, which in turn will affect its rivals' second stage choice of prices or quantities. Taking into account this additional strategic effect, Proposition 2 shows cellular firms will set access prices above even this higher monopoly level.

[8]This point has also been observed by Laffont and Tirole [2000], p. 184, and by Gans and King [2000].

Proposition 2 *Given (A3) and (A4) and a uniform fixed-to-mobile price, each cellular firm will set its access price above the monopoly level* a^U.

Proof. The effect of a change in a_i on π_i^a can be determined independently of the choice variable x_i in the second stage whenever all firms set the same access price ($a_i = a$). Evaluated at a point where all firms set the same access prices, the best response function (16) is determined without reference to to the choice variables $x_1, \ldots, x_n$. It is then possible to again determine how a change in a_i will affect termination profits per subscriber π_i^a as if this occurs in the first stage of the game. For a given P, the resulting change in π_i^a will then cause a change in the second stage choice variables exactly as before. In addition to changing π_i^a, an increase in a_i will decrease π_j^a for all $j \neq i$, by decreasing Q (through an increase in P). Again, evaluated at a point where all firms set the same access prices, this change in π_j^a can be treated as if it occurs in the first stage of the game. This additional strategic effect has to be taken into account.

Differentiating (5) with respect to a_i, and taking into account the envelope theorem, the total impact of a change in a_i on cellular profits at a point where $a_i = a$ for all i is then

$$\begin{aligned} \frac{d\pi_i}{da_i} &= \frac{\partial \pi_i}{\partial \pi_i^a}\frac{d\pi_i^a}{da_i} + \sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\frac{dx_j}{d\pi_i^a}\frac{d\pi_i^a}{da_i} + \sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\frac{dx_j}{d\pi_j^a}\frac{\partial \pi_j^a}{\partial Q}\frac{\partial Q}{\partial P}\frac{dP}{da_i} \\ &= -\left[\frac{\partial \pi_i}{\partial c_i^a} + \sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\frac{dx_j}{dc_i^a}\right]\frac{d\pi_i^a}{da_i} - \left[\sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\frac{dx_j}{dc_j^a}\frac{\partial \pi_j^a}{\partial Q}\frac{\partial Q}{\partial P}\frac{dP}{da_i}\right]. \end{aligned} \tag{19}$$

From (A3) the expression in the first square bracket will always be negative as before. Additionally, as argued above, an increase in a_i will decrease π_j^a (and equivalently increase c_j^a). From (A4) and the fact $\partial \pi_j^a/\partial Q > 0$ (provided $a_j > d$), the expression in the second square bracket will be negative. Thus, evaluating (19) at the monopoly access price (where $a_i = a^U > d$ for all i), $d\pi_i/da_i > 0$ and each cellular firm will want to set $a_i > a^U$. ■

Again it is insightful to interpret the findings in terms of a model in which two firms compete in prices. In this case, evaluated at the point $a_i = a_j$, (19) can be rewritten as

$$\frac{d\pi_i}{da_i} = \left[q_i - (p_i - c_i^a)\frac{\partial q_i}{\partial p_j}\frac{dp_j}{dc_i^a}\right]\frac{d\pi_i^a}{da_i} - \left[(p_i - c_i^a)\frac{\partial q_i}{\partial p_j}\frac{dp_j}{dc_j^a}(a_j - d)Q' f' s_i\right]. \tag{20}$$

As in the case of differential prices, if in the second stage equilibrium cellular firms earn zero profits, then in the first stage each cellular firm will set termination charges at the monopoly level. This follows from substituting $p_i - c_i^a = 0$ into (20). The intuition is the same as with differential pricing. If firms do not earn any profit per subscriber, then changes in the number of subscribers resulting from a change in the rival's price will not affect profits. Instead, firms will only face the direct impact on their profits from higher termination profits per subscriber.

With imperfect competition firms will earn positive profits for each subscriber they obtain, and in this case there are two indirect effects to take into account. The first, as with differential pricing, results from the decrease in firm j's price in response to firm i decreasing its price when termination profits per subscriber are increased. This will decrease the number of subscribers that firm i has, which will decrease firm i's profits. The second effect arises only because of uniform pricing, and results from the fact that under a uniform fixed-to-mobile price, increases in firm i's termination charge will decrease the demand for all fixed-to-mobile calls. A reduced demand for fixed-to-mobile calls will decrease the termination profit per subscriber that cellular firm j can earn (or equivalently increase its unit cost). In response, firm j will price less aggressively.[9] Other things equal, this increases the number of subscribers firm i obtains, and so its profit. This suggests that firms will have an additional incentive to inflate termination charges, to make their rivals act less aggressively in retail competition. As a result equilibrium termination charges will be above the monopoly level.

As termination charges are increased above the monopoly level there are two offsetting effects. On the one hand, termination profits per subscriber will decrease, which will decrease the cellular firm's profit. On the other hand, an increase in termination charges will reduce termination profits per subscriber that rivals can obtain, which will make rivals compete less aggressively in the cellular market. The greater is firm j's termination charge (and so margin on terminating calls), the more any fall in fixed-to-mobile demand will make it price less aggressively in the second stage of the game. This suggests that after both firms have increased their termination charge, as long as there is some remaining fixed-to-mobile demand, the incentive for each firm to further increase their termination charge may remain. In fact, it is possible that the equilibrium involves access prices set to the point where the fixed-to-mobile demand is eliminated (that is, $Q = 0$).

The case of the standard Hotelling market share function (7) shows that such an escalation in access prices is indeed possible. With a standard Hotelling model of competition, firm i sets an equilibrium price of

$$p_i = c + t - \frac{2}{3}\pi_i^a - \frac{1}{3}\pi_j^a.$$

which implies equilibrium profit for cellular firm i of

$$\pi_i = \frac{1}{2t}\left(t + \frac{1}{3}\left(\pi_i^a - \pi_j^a\right)\right)^2.$$

Note that while π_i^a is only increasing in a_i until the monopoly level a^U, π_j^a is decreasing in a_i until fixed-to-mobile demand Q falls to zero. At the point where both firms set the same termination charges, an increase in the termination charge by firm i decreases termination profits through a fall in fixed-to-mobile demand by exactly the same amount as it increases retail profits due to the rival firm becoming less aggressive. Each firm will then prefer to increase their termination charge above its rival so as to capture the direct effect of higher termination margins on each incoming call. Formally, whenever $a_i = a_j$,

$$\frac{d\pi_i}{da_i} = \frac{Q}{3} > 0.$$

Left to their own devices, the cellular firms will increase access prices above the monopoly level, and in fact to the point where the market for fixed-to-mobile calls is eliminated. In equilibrium, they still earn the normal Hotelling profits of $t/2$.

[9] This follows from (A2). With quantity competition, by (A1) firm j will react by decreasing output.

5 Common termination charges

One way to prevent cellular firms wanting to set access prices above the monopoly level is to require cellular firms agree on a common termination charge. Essentially, the escalation of termination charges arises from a coordination problem. If firms have to set a common termination charge, then at least when firms are symmetric, no single firm can gain market share by increasing the common access charge. As a result, firms will not have any incentive to inflate the common access price above the monopoly level a^D. This result does not depend on whether there are differential or uniform fixed-to-mobile prices, since with a common access price, the fixed-to-mobile prices will anyway be the same. Proposition 3 characterizes the choice of a common access price.

Proposition 3 *Given (A7), cellular firms will set a common access price at the monopoly level a^D. If instead (A7$'$) holds, cellular firms will be indifferent over the setting of common access price.*

Proof. To work out how a change in the common access price a affects cellular profits, note the derivative of π_i with respect to a can be decomposed in a similar way to before. With a common access price, the best responses (2) are determined without reference to $x_1, \ldots, x_n$, so again it is possible to first determine how a change in a will affect termination profits per subscriber $\pi_1^a, \ldots, \pi_n^a$ as if this occurs in the first stage of the game. Note from the fact both a and P are common, all firms' termination profits per subscriber will change by the same amount. For a given P, a change in $\pi_1^a, \ldots, \pi_n^a$ will then cause a change in second stage choice variables exactly as before.

Taking into account the envelope theorem, it follows that

$$\begin{aligned} \frac{d\pi_i}{da} &= \frac{\partial \pi_i}{\partial \pi_i^a}\frac{d\pi_i^a}{da} + \sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\left(\sum_{k\neq j}^{n}\frac{dx_j}{d\pi_k^a}\frac{d\pi_k^a}{da}\right) \qquad (21) \\ &= -\left[\frac{\partial \pi_i}{\partial c_i^a} + \left(\sum_{j\neq i}\frac{\partial \pi_i}{\partial x_j}\left(\sum_{k\neq j}^{n}\frac{dx_j}{dc_k^a}\right)\right)\right]\frac{d\pi_i^a}{da}. \end{aligned}$$

If (A7) holds, the expression in the square bracket will always be negative. Thus, $d\pi_i/da_i$ is always the same sign as $d\pi_i^a/da_i$, and each cellular firm's profit π_i will be maximized by maximizing π_i^a, where $\pi_i^a = (a-d)Q(P)$ and $P = f(C+a)$. From (9) this is achieved by setting $a_i = a^D$.

If instead (A7$'$) holds, the expression in the square bracket will be zero. In this case $d\pi_i/da_i = 0$ regardless of a_i, and firms will be indifferent over the setting of the common termination charge. ■

In the case of two firms that compete in prices, the first-order conditions $\partial\pi_i/\partial p_i = 0$ imply (21) can be rewritten as

$$\frac{d\pi_i}{da} = q_i\left[1 + \frac{\frac{\partial q_i}{\partial p_j}}{\frac{\partial q_i}{\partial p_i}}\left(\frac{dp_i}{dc_i^a} + \frac{dp_j}{dc_i^a}\right)\right]\frac{d\pi_i^a}{da}. \qquad (22)$$

Typically, although not always, $\frac{\partial q_i}{\partial p_j} \leq -\frac{\partial q_i}{\partial p_i}$ and $\frac{dp_i}{dc_i^a} + \frac{dp_j}{dc_i^a} < 1$, so the expression in the square brackets is positive. This 'typical' case is captured by the assumption (A7). In this case firms maximize their profits by jointly minimizing their costs. Consequently, cellular firms will mutually want to set a common termination charge at the monopoly level (a^D).[10]

[10]The special case in which the expression in the square bracket is zero occurs when (A7$'$) holds. (A7$'$) says cellular firms' profits are invariant to an equal change in the marginal cost of all firms, as is the case for instance with the standard

6 Extensions

This section discusses some important extensions of our model. In Section 6.1 the model is extended to handle the case in which cellular customers care about receiving calls and/or the utility of those making fixed-to-mobile calls. The possibility that receivers pay for receiving calls is also discussed. Section 6.2 provides some insights on how results extend when calls from mobile subscribers are incorporated. Welfare implications of different termination charges are examined in Section 6.3.

6.1 Receivers care and receivers pay

The first extension we consider is to the case in which cellular customers care about either how many calls they receive (for example, a small business that advertises its phone number) and/or the utility obtained by the people calling them (for example, people may care about the price friends and family have to pay to reach them). Previously the demand for cellular subscriptions q_i was assumed not to depend on the price of fixed-to-mobile calls. This requires that cellular subscribers do not care how much people pay to call them.

Allowing receivers to care about the price of fixed-to-mobile calls will not matter when the fixed-line network sets a uniform price, since any individual's choice of network will not affect the price paid by fixed-line callers. With differential fixed-to-mobile prices, people may be willing to join a more expensive cellular firm, if as a result fixed-line callers pay less to call them. This case can be illustrated by making use of the Hotelling model of competition introduced in Section 2.[11]

Specifically, suppose in addition to the standard utility $v - p_1 - tx$ from subscribing to firm 1 and $v - p_2 - t(1 - x)$ from subscribing to firm 2, cellular subscribers obtain additional utility of $B(P_i) = \beta Q(P_i) + \gamma V(P_i)$ from joining firm i, where $V(P_i) = U(Q(P_i)) - P_i Q(P_i)$ is the indirect utility fixed-line callers get from making $Q(P_i)$ fixed-to-mobile calls to each cellular subscriber. The parameter γ is the weight (between zero and one) that cellular subscribers put on the utility of people calling them from the fixed-line network, and β measures the marginal benefit receivers obtain from each incoming call.

Solving for firm i's market share using the standard Hotelling approach of finding the location of the consumer that is indifferent between the two firms implies

$$q_i = \frac{1}{2} + \frac{(B(P_i) - p_i) - (B(P_j) - p_j)}{2t}.$$

Given π_i^a, π_j^a, P_i, and P_j, firm i's equilibrium price is

$$p_i = t + c - \frac{2}{3}\pi_i^a - \frac{1}{3}\pi_j^a + \frac{1}{3}(B(P_i) - B(P_j)).$$

Consistent with our earlier results, both firms decrease their prices with an increase in their, or their

Hotelling market share function (7). In this case any extra termination profits are fully competed away, and so there is no mutual benefit of a higher or lower termination charge.

[11] This section builds on Armstrong [2001], who obtains similar results assuming cellular firms are perfectly competitive.

rival's, termination profit per subscriber. The profit for cellular firm i is

$$\pi_i = \frac{1}{2t}\left(t + \frac{1}{3}\left(\pi_i^a + B(P_i) - \pi_j^a - B(P_j)\right)\right)^2. \tag{23}$$

Firm i's profits in (23) are maximized by choosing a_i to maximize $\pi_i^a + B(P_i)$. Provided we maintain the assumption that the fixed-to-mobile price P_i can be written as the increasing function f of costs $C + a_i$ only (as will be the case when fixed-to-mobile prices are set at perceived cost), the first-order condition from this maximization problem is

$$Q(P_i) + (a_i - d + \beta)Q'(P_i)f' + \gamma V'(P_i)f' = 0. \tag{24}$$

Making use of the fact that $V'(P_i) = Q(P_i)$, equation (24) implies

$$a_i = d - \beta - \frac{(1 - \gamma f')Q(P_i)}{Q'(P_i)f'}. \tag{25}$$

In the special case in which fixed-to-mobile prices are set exactly at cost (so $f' = 1$), a_i is less than the monopoly level a^D defined in (10). There are two reasons firms will set termination charges below a^D.

First, the firms' profit maximizing access price is less than a^D to the extent that cellular subscribers care about receiving calls ($\beta > 0$). In this case, lowering the access price is a way to attract additional customers. Starting from the monopoly access price (which maximizes termination profit per subscriber), if firm i decreases its access prices a small amount this has no effect on termination profits per subscriber. However, by increasing the benefit it offers to cellular subscribers, it attracts additional customers to firm i, thereby increasing its profit. Unambiguously, firm i will want to set access prices below the monopoly level.

Second, to the extent cellular subscribers put some weight on the utility of fixed-line callers ($\gamma > 0$), the monopoly markup in (25) will be reduced. In the extreme case in which cellular subscribers care as much about fixed-line callers' utility as their own utility ($\gamma = 1$) and do not care about receiving calls ($\beta = 0$), cellular firms will set access prices exactly at cost $a_i = d$.[12] In practice, cellular subscribers will in general weight their own utility higher than those calling them, and the problem of inflated access prices will persist. The fact receivers care, does not overturn our earlier results, although it may soften them somewhat.

Our analysis also assumed cellular subscribers did not face a separate fee for receiving calls. This is not necessarily a restrictive assumption. As long as the fee charged for receiving calls is significantly lower than the fee charged for making calls, reception fees should not matter since they will not affect total call volume (which will be determined by the price paid by fixed-line customers for originating calls). In this case, any fee charged for receiving calls can be subsumed into the subscription charge p_i faced by cellular subscribers. For this reason, without any regulatory constraint on access charges, cellular firms may never choose to use reception fees. This may explain why in countries where cellular firms are able to set 'high' termination charges, cellular subscribers are not charged for receiving calls.

[12] If $f' < 1$ then even if $\gamma = 1$ and $\beta = 0$, firms will set access prices above cost. When the fixed-line network absorbs some of any increase in termination charges above cost, cellular firms can still offer cellular customers more by setting a termination charge above cost.

If the mobile phone companies ability to set the access charge is constrained (either for technological or regulatory reasons), then they may be forced to set reception fees to the point where the total volume of traffic will depend in part on the fees charged to receivers. This scenario is applicable to the United States. In the United States cellular networks do not have distinct access codes, so a consumer cannot tell whether a call is to the fixed-line or cellular network. To prevent networks taking advantage of this customer ignorance, fixed-to-mobile calls are generally priced as normal local calls, and cellular subscribers are charged for receiving calls. This situation has been analyzed by Hermalin and Katz [2001], Jeon et al. [2001], and Kim and Lim [2001].[13]

6.2 Allowing for other types of demand

This section briefly explores the implications of extending our model to incorporate demand for calls by cellular subscribers, both to other cellular subscribers and to the fixed-line network.

Taking into account the demand for calls from the cellular subscribers to the fixed-line network is straightforward as long as the demand for such calls does not depend on the price charged for fixed-to-mobile calls. In this case, firms will compete over outgoing mobile calls in a normal fashion. Where cellular firms set subscription fees, they will optimally recover all profits through such charges, and set the price for outgoing calls at perceived marginal cost.[14]

When the possibility of call-back is taken into account, so that cellular subscribers can call back fixed-line callers when the price for such calls is significantly below the price of fixed-to-mobile calls, the incentive for cellular firms to increase termination charges above cost is weakened. Essentially, call back makes the demand for fixed-to-mobile calls more elastic, and thus lowers the 'monopoly' access price that cellular firms set.

Taking into account calls to other cellular subscribers is more difficult. Given not everyone has a cellphone, utility from cellular subscription will depend on how many other people subscribe to the cellular network. The resulting network externality makes analysis of cellular competition more difficult, although as Wright [1999] demonstrates with a calibrated model, it does not necessarily change the qualitative results.

Mobile-to-mobile calls also gives rise to substitution possibilities. People with cellphones will compare the price of mobile-to-mobile and fixed-to-mobile calls. To the extent mobile-to-mobile prices are cost based, this clearly limits the amount of termination revenue that can be raised by increasing termination charges above cost. Again, this type of substitution makes the demand for fixed-to-mobile calls more

[13] Empirical comparisons of pricing behavior across receiver pays and caller pay regimes could provide a test of the different implications of these models from the present one. The model in this paper suggests high fixed-to-mobile termination charges will lead to lower overall cellular charges. The lack of such termination revenue could help explain the slower growth of cellular subscriptions in the United States compared with other developed countries, especially when other factors such as GDP per-capita are taken into account. Alternatively, charging receivers for calls may have other negative consequences. Interestingly, cellular-phone service soared in Mexico after it introduced caller pays in May 1999 (subscriber growth peaked at a 130.8% annual growth rate in 1999).

[14] See for instance, Armstrong [2001], Gans and King [2000], and Wright [1999]. This of course assumes that the termination charge cellular firms face for mobile-to-fixed calls is regulated or otherwise predetermined.

elastic, and thus lowers the 'monopoly' access price which cellular firms set.

6.3 Welfare implications

The analysis of previous sections has shown that, free of regulatory constraints, cellular firms will tend to set above-cost access prices. However, significant margins on access do not automatically imply access charges are set too high from a welfare perspective. When people already have access to a fixed-line network, while many do not have access to a cellular network, the socially optimal termination charge can in fact be much higher than cost. Above-cost termination charges lower cellular prices which is beneficial when there is imperfect competition in the cellular sector. Fixed-line subscribers and existing cellular subscribers also benefit from being able to call (and be called by) the new cellular subscribers. Even if the effects of double marginalization (which arises from access prices and fixed-to-mobile prices being set above respective costs) is taken into account, the welfare maximizing termination charges can still be high. In the calibrated model of Wright [1999], which captures all of the effects described here, the socially optimal termination charge turns out to be several times cost even when fifty percent of consumers have cellular subscriptions in equilibrium.

Although there are sound arguments for the regulator to set termination charges above cost when there is partial participation in the cellular sector, this does not imply the termination charges chosen by cellular firms are likely to be welfare maximizing. In fact, since the monopoly access price maximizes termination profit per subscriber, a small decrease in the termination charge will not affect cellular subscription prices or profits at the margin, but will increase welfare through lower fixed-to-mobile prices. Therefore, welfare will generally be maximized for termination charges below those set by competing cellular firms.

7 Applications to other markets

Our model of cellular firms competing to gain customers, and so termination revenue, has implications for a number of network settings.[15] Here four such applications are considered.

7.1 Termination of long-distance calls

Most directly our model applies to local exchange carriers that compete for local subscribers and earn termination revenue off these subscribers — for instance, from terminating incoming long-distance traffic. With the emergence of facilities based local competitors, one can use our model to address whether such competition by itself will result in termination charges being set at cost. For instance, in the United States, for a long-distance call to be provided the long-distance operator requires access to the particular local exchange to which the person being called subscribes.

[15] An application in quite a different setting is to the sale of wedding photography services, in which firms compete to provide couples with photography services, but also sell the wedding photos (via the Internet) to the friends and family of the couple. Although firms may compete aggressively to attract couples, once 'captured', they can price access to their wedding photos to third parties at monopoly levels.

Where competing local carriers are free to set termination charges, our model predicts either they will set them at the monopoly level (Proposition 1) or, if long-distance operators are unable to set differential prices to reflect different termination charges, they will set them above the monopoly level (Proposition 2). The inflated termination charges for long-distance calls will result in low subscription fees for local calls, and inflated long-distance prices. Future research ought to explore this possibility, taking into account the two way nature of long-distance calls.[16]

7.2 Termination of ISP bound calls

A related application is to the recent emergence of local exchange carriers that specialize in terminating Internet Service Provider (ISP) bound calls. ISPs provide subscribers with Internet access. To dial into their ISP, these subscribers place calls, typically using the incumbent local exchange carrier. Where the ISP is signed up to a competing local exchange carrier, the competing carrier terminates these calls. In the United States and some other countries it appears above-cost termination charges have led to greater competition and lower pricing for ISPs (and consequently their customers) at the expense of the incumbent fixed-line network.[17]

The competition to attract ISP subscribers so as to terminate ISP-bound calls differs in at least one important respect from the competition to attract cellular customers modeled in this paper. With ISP-bound calls the calling party directly benefits from high termination charges. This differs from cellular termination, where the fixed line caller decides how much to call, and the cellular subscribers benefit from the termination revenue derived from these calls through lower subscription fees.

If the incumbent local exchange could pass on the costs of terminating ISP-bound calls to its subscribers, since the caller and the called party are one and the same, there would be little incentive for competing exchange carriers to inflate termination charges. The incentive ISPs face to inflate termination charges instead arises because the retail price of an ISP-bound call is typically capped, usually at the same rate as a regular local call (which in a number of jurisdictions is required to be offered with no per-minute or per-call charge). In this case it is the incumbent network (rather than the fixed-line caller) that is forced to subsidize ISPs for above cost termination charges, and fixed-line networks may well lose money on each ISP-bound call they originate.[18]

7.3 International call settlement

Our model also applies to the termination of international calls by long-distance operators. Under proportional return in the United States, long-distance operators get a share of the terminating revenue from international carriers that is proportional to their share of outgoing international calls. Our model

[16] Carter and Wright [1999] consider a model of two-way fixed-line interconnection that also incorporates termination revenue arising from the demand from the origination and termination of long-distance traffic.

[17] See Wright [2001a] for a discussion and some analysis of the efficient pricing of the termination of ISP bound calls.

[18] Incumbent phone companies in the United States gave entrant carriers over two billion dollars in compensation during the year 2000 without seeing reciprocal fees. For details, see the letter from W. Scott Randolph, Verizon Communications to Magalie R. Salas, Secretary, FCC (Nov 1, 2000), filed in Docket No. 99-68.

predicts that this will lead to more intense competition for outgoing international calls as firms compete to gain outgoing traffic, and therefore the lucrative termination revenue such traffic generates.

7.4 Setting interchange fees in payment systems

The competition for termination revenue also arises in electronic payment systems such as credit and debit card systems. In these systems, banks both issue cards to consumers (such banks are known as issuers) and also acquire merchants who accept cards (such banks are known as acquirers). For any given card transaction, an interchange fee is typically paid from the card acquirer to the card issuer. Since there is competition between issuing banks to sign up cardholders, the higher the interchange fee, the lower the cardholder fees (or the higher the cardholder rebates). Moreover, since merchants generally set a uniform price for goods regardless of how their customers pay, cardholders will not face an offsetting fee for using their cards for payment.

Rochet and Tirole [2000] model a payment scheme in which issuers and acquirers are not symmetric. They allow issuers to jointly set a single interchange fee to acquirers. This case mirrors that looked at in Section 5 in which cellular firms set a common termination charge. Rochet and Tirole find that issuers will agree to set the interchange fee at the same level that a monopolist issuer would set. In their model this is the highest level at which merchants, which are all assumed to be identical, still accept cards. As a result, consumers will generally face low (or negative) fees for paying with credit cards, while merchants will face relatively high fees. Due to the structure of their model, this can lead to an overprovision of credit cards.

In models of credit card payment systems that allow both issuers and acquirers to determine the interchange fee, and where both cardholder and merchant demand matters, Schmalensee [2001] and Wright [2001b] show that the level of the interchange fee set by issuers and acquirers will depend on the relative bargaining power of the two sides, among other things.

Even in such models there is one case where an extreme asymmetry between issuers and acquirers arises. Given the 'honor all cards' rule under which credit card systems operate[19], if interchange fees are required to be set bilaterally between each issuer and each acquirer, card issuers will tend to have a lot more negotiation power than acquirers.[20] If the acquirer does not agree to any issuer's terms of interchange, it risks its merchants not being able to accept any cards of the same brand. With issuers having hold-up power under bilateral bargaining, the analysis of this paper applies. Since any reduction in demand from merchants caused by a single issuer raising its interchange fee reduces demand faced by all issuers, the analysis of Section 4 applies. Proposition 2 suggests the result will be that interchange fee will be set above the monopoly level. The resulting extreme imbalance in pricing will likely dramatically

[19]The honor all cards rule says that if a merchant accepts a Visa card issued by one bank, it must also accept all other Visa cards regardless of the issuer or the particular type of Visa card.

[20]Bilateral setting of interchange fees may be required to avoid policy makers' concerns over the apparent "agreement between competitors" that arises when the banks that compete as issuers and acquirers cooperate to set the interchange fee paid between themselves. Balto [2000] suggests that issuers and acquirers should be required to negotiate interchange fees bilaterally rather than be allowed to set them centrally.

reduce the size of the credit card network. Small and Wright [2001] confirm this finding for a specific model of bilateral interchange fee setting in a credit card network.

8 Conclusions

This paper has studied access pricing in an increasingly common situation — where firms compete for customers and also set prices for third parties to access these customers. We found that in such cases, upstream competition does not solve the standard access pricing problem (of access prices being set by a bottleneck at the monopoly level), and in the case of uniform downstream prices, can lead to even higher access prices. However, above-cost access prices need not lead to high profits. Instead, as upstream rents are competed away, they will be manifested in low prices to upstream customers and high prices to downstream customers.[21]

To make our discussion and modelling concrete we couched our model in terms of the termination of fixed-to-mobile calls. Several policy implications arise in this context. Allowing the fixed-line network to set differential prices to reflect different cellular termination charges helps prevent an escalation of termination charges above the monopoly level and, as such, should be encouraged. Alternatively, if uniform fixed-to-mobile prices are required, allowing cellular firms to coordinate over the setting of a common termination charge may help prevent the escalation of termination charges above the monopoly level. To further lower termination charges, a price-cap on the termination charges set by cellular firms may be needed, although welfare is unlikely to be maximized by setting the price-cap equal to cost.

The monopoly pricing problem analyzed in this paper arises, in part, from an asymmetric regulatory approach. Typically, fixed-line networks have to terminate mobile calls at cost, while cellular firms are free to set termination charges for fixed-line calls. Where there is competition on both sides of the market, an alternative to regulating termination charges of fixed-line and cellular firms may be to let both types of network negotiate their termination charges freely. As long as the firms' bargaining power is roughly balanced, the tendency for cellular firms to set high termination charges may be alleviated.

High termination charges raise the possibility of antitrust claims. For instance, in 1999 MCI World-Com filed a formal antitrust complaint against five European mobile-phone operators, alleging the five were abusing their dominant positions in local markets by charging high termination charges (Mitchener [1999]). According to the complaint, mobile termination charges within the same country were 52% higher than mobile-to-fixed charges and up to 700% higher than fixed-to-fixed charges. As a result, it

[21] The dissipation of upstream rents by cellular firms bears some resemblance to the competition for market share that arises in the switching cost literature (see section 3.2 of Klemperer [1995] for instance). In a standard switching cost model, high profits are to some extent dissipated by the firms' attempts to acquire the 'captive' customers in the first place. There are important differences, however. With switching costs it is the *prospect* of high prices and profits in the aftermarket that leads to the dissipation of profits. In contrast, here the competition for market share is the *result* of high (access) prices being set to fixed-line customers. One consequence of this timing difference is the strategic effect studied in Section 4 in which access prices are set above the monopoly level so as to make rival firms less aggressive in competing for customers. In contrast, with switching costs, ex-ante competition may reduce the incentive to exploit market power in the aftermarket when reputational effects matter.

was claimed, European customers were being overcharged by \$U.S. 3.61 billion. Our model suggests, due to competition to capture this lucrative termination revenue, cellular firms may well have competed away much of the higher termination revenue under dispute. Where upstream firms dissipate most of the termination revenue (to their customers), but retain the litigation risk for damages associated with collecting the revenue, then the upstream firms would appear to have a strong incentive to act collectively to avoid inflated termination charges. The difficulty is that competitors will be reluctant to act collectively where this is itself per-se illegal.

A common theme throughout the paper was that competition between network providers will not necessarily lead to the efficient pricing between the different sides of the network (for example, between cellular and fixed-line callers). We discussed the application of this principle to other market settings, including to the competition between local exchange carriers to attract local subscribers so as to terminate more long-distance calls, the competition between local exchange carriers to provide Internet access so as to earn lucrative termination revenue on ISP bound calls, and the competition between issuing banks in debit and credit card schemes to attract cardholders so as to earn interchange revenue. Future research ought to explore the extent to which cooperation between the different network providers (for example, cellular and fixed-line networks), or vertical integration, can eliminate the distortion in prices which competition alone does not solve.

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