

Mobile Termination

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1 Introduction

Regulators in Australia, Japan, United Kingdom and many countries in Europe have regulated mobile termination rates reflecting concerns about the high level of these charges and the resulting high fixed-to-mobile retail prices. In Latin American countries, despite success in expanding mobile telephony, the relatively high charges imposed by mobile phone operators on fixed line networks to accept calls have led to recent calls for regulatory intervention. For example, regulatory agencies in Colombia, Panama, Uruguay and Argentina have included mobile termination in their agenda.

Theoretical support for the possibility fixed-to-mobile prices may be set too high comes from models provided by Armstrong (2002), Gans and King (2000) and Wright (2002). This theory is based on the simple idea that mobile operators have a monopoly on terminating calls to *their customers* from fixed-line callers, which they will exploit by setting high fixed-to-mobile termination charges.

Wright (1999, 2002) analyses a positive implication of such high termination charges. Competition to collect this lucrative termination revenue drives mobile operators to set low mobile charges, so as to attract subscribers to their network and thereby collect more termination revenue. Through competition, the revenue from termination may be largely passed back to mobile consumers. In situations where mobile participation is

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limited, this can spur more people to get mobile phones, which provides positive spillovers both to fixed-line users and other mobile phone users.¹

Thus, in markets with incomplete cellular penetration it is not clear whether current termination charges, even if above cost, are set too high. Wright (1999) provides a numerical example to show that with partial mobile penetration, the socially optimal termination charge could in fact be many times costs. This chapter builds on this approach by calculating the welfare effects of lowering termination charges in a selected Latin American country by calibrating a theoretical model to market conditions in Colombia. Countries such as Colombia are of interest since they involve markets where (a) mobile penetration is still quite low – less than 30 per cent for most Latin American countries², and (b) policymakers are considering regulating lower termination charges.

The theoretical model that is calibrated is similar to Wright (1999) but extends his model in several dimensions. First, the model here allows for any number of mobile firms to compete. This is done using a generalized product differentiation framework in which all mobile operators compete directly with all others (unlike the Salop model), and they need not be symmetric. Second, the model captures the realistic aspect that firms set two-part tariffs, but still markup unit prices above cost. This is modeled by allowing consumers to vary in their intensity of demand, while restricting firms to offer a single two-part tariff. This reflects the fact that firms may want to keep their pricing plans relatively simple even in the face of heterogeneous consumers. Third, the model is

¹ There is also an indirect mechanism by which high termination charges can increase mobile subscriptions, which has not previously been noted. An increase in fixed-to-mobile termination charges increases fixed-to-mobile retail prices, which increases the demand for mobile subscription from people who want to call mobile subscribers that are away from a landline, but want to avoid the high fixed-to-mobile prices.

² Chile and Mexico have the highest mobile penetration, but is still under 50 per cent.

matched to actual data on Colombia.

We calibrate the model using recent data on the Colombian market. The relevant data are the mobile penetration rate, the number of mobile firms and their market shares, the costs of service provision (unit costs and annual rentals for mobile-to-mobile, mobile-to-fixed and fixed-to-mobile service) and the elasticities of demand for each call type.

The simulation results show that consumer surplus³, fixed-to-mobile traffic and mobile penetration are all increasing functions of the termination charge in the region of the current termination charge (± 5 cents). However as the termination charge continues to increase consumer surplus begins to decline. This is because, as termination charges increase at some point the positive impact on termination profits, and so the impact on expanding mobile penetration weakens, while the negative impact on higher fixed-to-mobile prices becomes more significant. The point at which total consumer surplus is maximized is around 7 cents above the current termination charge. A similar effect occurs for fixed-to-mobile traffic, which initially rises due to the impact of rising mobile penetration rates but then falls due to falling fixed-to-mobile demand caused by rising fixed-to-mobile prices. Surprisingly, fixed-to-mobile traffic is actually maximized at around 6 cents *above* the current termination charge, consistent with strong positive spillovers from greater mobile penetration on fixed line users.

The rest of the chapter is laid out as follows. In Section 2 we briefly review the main literature on fixed-to-mobile termination charging, discussing along the way the idea of receiver pays, which is sometimes touted as an alternative (light-handed) policy to

³ The sum of consumer surplus from mobile and fixed-line consumers.

regulating termination charges. Section 3 presents our theoretical model. Data and the calibration exercise are given in Section 4, while Section 5 presents the results and welfare analysis. Section 6 briefly concludes, and offers some directions for future research.

2 Literature review

In this section we review the recent literature that analyses fixed-to-mobile call termination.⁴ We start by reviewing the theoretical literature on the socially optimal level of the fixed-to-mobile termination charge, and models which explain how unregulated mobile operators should in theory set fixed-to-mobile termination charges. We then offer our perspective on a recent literature which promotes receiver pays as an alternative to regulating fixed-to-mobile termination charges.

Armstrong (1997) noted the high price of fixed-to-mobile calls in the U.K. (in July 1996 the average per-minute retail charge for fixed-to-mobile calls was around 25 pence) and provided a simple model of fixed-to-mobile calls to examine the socially optimal level of these charges. In a model of perfectly competitive mobile operators, he shows that the socially optimal termination charge should be set below cost to the extent the price of fixed-to-mobile calls involves a margin above the termination cost (to avoid double marginalization), should be set below cost to the extent mobile subscribers get utility from receiving calls (to internalise the externality to call receivers), but should be set above cost to the extent this affords a subsidy to mobile subscribers which encourages more mobile subscription (since this benefits fixed-line consumers, who can now make

⁴ See Gans et al. (forthcoming) for a more general literature survey on mobile telephony.

more fixed-to-mobile calls).

Wright (1999) considers (numerically) a model of partial mobile penetration which has the first and third feature above. In addition, by capturing imperfect competition in the mobile sector, and allowing for mobile-to-mobile calls, he captures two additional effects to those noted by Armstrong. In this setting, a subsidy to mobile subscribers from high termination charges means *existing cellular subscribers* as well as fixed-line subscribers benefit from being able to call new mobile subscribers who join because of subsidised subscription charges. Efficiency is also enhanced by above-cost termination charges given there is imperfect competition between mobile operators. This “monopoly subsidy” effect works in the other direction to that on the fixed-to-mobile side, where low termination charges help reduce the monopoly markup on fixed-to-mobile prices and so increase efficiency. Wright takes into account all these various effects and finds using a numerical example that the socially optimal termination charge can be several times cost when the mobile penetration rate is around fifty percent.

Gans and King (2000), Wright (1999, 2002) and Armstrong (2002) model how competing mobile operators will want to set their termination charges to a single fixed-to-mobile operator. These models assume a given number of fixed-to-mobile subscribers choose the number of fixed-to-mobile calls.⁵ Gans and King consider the case in which the fixed line network can set differential fixed-to-mobile prices depending on which mobile operator the calls terminate on, but where consumers are ignorant about which mobile network they are calling. Wright (1999) makes a formally equivalent assumption, that a uniform fixed-to-mobile price is set. Armstrong (2002) and Wright (2002) consider

⁵ The fact that fixed and mobile subscribers do not jointly determine the number of fixed-to-mobile calls is broadly consistent with the fact that in equilibrium it is the fixed-line caller that pays for the call.

fixed-to-mobile prices that can differ depending on which mobile network is called. In all cases, competing mobile operators set their termination charges at, or even above, the level that a single (monopoly) mobile operator would choose to charge to the fixed-to-mobile network.

In these models, mobile operators do not internalise the profits of the fixed-to-mobile network, nor the surplus of fixed-to-mobile callers when setting their termination charges. Rather, they seek to maximize termination profit, if only so they can provide the maximum subsidy to their subscribers. There are however some reasons why the resulting termination rates may not be so high (or too high).

Armstrong (2002) considers the case in which mobile subscribers internalise the benefits of those calling them (for example, they might care about the price friends and family pay to call them). This makes mobile subscribers less inclined to join a network that offers cheap subscription only because it is expensive for others to call the network.⁶ In this setting, mobile carriers will have less incentive to set high termination charges.

Similarly, as mobile penetration increases, mobile-to-mobile calls will increasingly be an important substitute for fixed-to-mobile calls. If consumers are charged too much for making fixed-to-mobile calls, they will simply make mobile-to-mobile calls instead. This substitution possibility should help constrain the ability of the fixed-line operator to mark up fixed-to-mobile calls. To the extent that mobile-to-mobile calls are cost based, this will also undermine the ability of mobile carriers to raise their fixed-to-mobile termination charges much above cost. Essentially, fixed-to-mobile

⁶ Such subscribers may still join a cheaper network funded by high fixed-to-mobile termination charges since they can always take advantage of cost-based mobile-to-fixed prices to call back fixed-to-mobile callers. This tends to make fixed-to-mobile demand more elastic, and the monopoly fixed-to-mobile termination charge lower.

demand will become more elastic, lowering the monopoly termination charge towards cost.⁷

The monopoly pricing in call termination is heightened by an asymmetric regulatory approach. Typically, the fixed-line network has to terminate mobile calls at cost, while mobile operators are free to set termination charges for fixed-line calls. To the extent the fixed-line network has bargaining power, perhaps because mobile operators also require services from it (and these services are not regulated), then the resulting negotiated termination charges should be lower than that predicted by the Armstrong, Gans and King, and Wright models.

It is worth noting that even if mobile operators do set termination charges at the monopoly level, their bottleneck over mobile termination does not imply mobile operators have market power. Since market power is defined as the ability of firm(s) to profitably set a price above the competitive level, and since in this setting perfectly competitive mobile operators may set the same termination charges as a single monopoly operator, by definition operators cannot be said to have any market power in call termination. Instead, market power is more usefully defined over the full range of retail services that the operators provide, in which case it will relate to the general competitiveness of the mobile sector.

A related literature to that discussed above considers receiver-pays as an alternative approach to dealing with the monopoly call termination problem (see Doyle and Smith, 1998; Crandall and Sidak, 2004; and Littlechild, 2004). The idea is that by charging receivers directly, mobile operators need not charge high termination charges,

⁷ This also suggests the analysis of mobile-to-mobile termination charges may be quite closely tied to that of fixed-to-mobile termination.

and so the call termination problem is avoided. For instance, Doyle and Smith consider a set-up in which the fixed-to-mobile caller pays a price equal to the normal price of a fixed-line call. The mobile subscriber receiving the call makes up the difference between the posted price of a fixed-to-mobile call, set by the mobile operator, and the lower charge paid by the fixed-line caller. They argue under this receiver pays principle, prices will be lower.

Crandall and Sidak (2004) and Littlechild (2004) go further, promoting receiver pays as a light-handed alternative to regulating termination charges. However, it is not clear from this literature how allowing receivers to pay, without some other explicit or implicit regulatory intervention (such as that considered by Doyle and Smith) solves the call termination problem. In fact, if the models of Armstrong, Gans and King, and Wright are extended to allow receivers to also pay, this would not change the incentive of mobile operators to set termination charges at the monopoly level. Put simply, whether mobile operators can charge their subscribers for receiving calls, or just for subscription, does not change their general incentive to charge the fixed-line network for terminating calls to its customers.

Given that “for RPP countries generally the termination charge is negligible or zero” (Littlechild, 2004), this suggests some other aspect of these receiver pay regimes is effectively regulating termination charges to zero. Seen in this light, the proponents of receiver pays regimes are actually promoting even more drastic regulation of termination charges – to set them to zero. In fact, it may be better to think of receiver pays as the outcome rather than cause of low termination charges. Regulation of zero termination charges in a competitive mobile sector will lead mobile operators to charge receivers for

incoming calls to recover their marginal costs of receiving calls. In contrast, with high termination charges, operators would not want to charge their subscribers for receiving calls, since this will reduce the number of calls they terminate and their termination revenue (as say their subscribers turn off their phones, or shorten their conversations). Thus, caller pays will endogenously arise when high termination charges are allowed, while receiver pays will endogenously arise when low termination charges are regulated.

3 Theoretical model

In this section we detail the theoretical model used to do our welfare analysis of fixed-to-mobile termination charges. It is closest to the model presented in Wright (1999), but extends his model to allow for any number of mobile firms to compete using a generalized product differentiation framework and to allow for heterogeneous consumer demand for calls. The first extension allows us to handle the fact in the Colombian market, there are three competing mobile firms. It can be applied to other markets with more than three firms. The second extension is important since it helps explain why unit prices are set above marginal cost even though firms set two-part tariffs, which seems to be the case.

Wright's model was based on the Hotelling model. Rather than extending his model to allow for J firms using the Salop model, which assumes each firm only competes directly with its two closest competitors we use instead an extension that allows all mobile operators compete directly with all others. This puts firms on the vertexes of a $J-1$ dimensional simplex, with consumers uniformly distributed along the edges of this simplex. Brand loyalty (or asymmetry in operators) is modeled in the same way as

Wright, so that consumers' utility has an operator (or brand) specific effect (which differs across each operator but in the same way for all consumers). The model thus combines both vertical and horizontal differentiation with J -firm competition in a tractable way.

3.1 Model derivation

We consider a market comprising $j = 1, \dots, J$ mobile-telephony firms and a single non-integrated fixed line firm. Each mobile firm chooses the level of its rentals and its unit prices to maximise profit given the prices and rentals of its competitors. The services provided by the firms are purchased by $i = 1, \dots, N$ consumers. Consumers are differentiated by their preference for each mobile firm and by their willingness to pay for mobile calls.

The utility functions of consumers comprise two main components:

- (i) utility arising from making telephone calls ('call-related benefits'); and
- (ii) utility arising from subscribing to a particular mobile network operator ('network benefits').

These two factors are combined additively and are summed across consumers to yield total consumer benefits.

Consumers make three types of calls involving mobile firms: mobile-to-mobile calls, mobile-to-fixed calls and fixed-to-mobile calls. For a given consumer, the utility derived from mobile-to-mobile calls depends not only on the desired number of call minutes made, but also on the number of other mobile subscribers that can be reached. Therefore we write the utility function of a representative consumer as

$$(1) \quad u_i(q) = \rho a_i q^{(\varepsilon-1)/\varepsilon},$$

where $a_i \sim U[a_{\min}, a_{\max}]$ with $0 \leq a_{\min} < a_{\max} < \infty$ and $\varepsilon > 1$ is the price elasticity of demand. The term ρ is the mobile telephone penetration rate (defined below) and q is the quantity of mobile-to-mobile call minutes demanded by one mobile subscriber to another. The variable a_i allows the utility derived from a given quantity of call minutes to vary across consumers. Given prices, consumer i 's demand for service from mobile firm j solves

$$(2) \quad w_{i,j}^m = \max_q \{u_i(q) - \rho p_j q\},$$

which yields the demand function

$$(3) \quad q_{i,j}^m = \left(\frac{a_i \delta}{p_j} \right)^\varepsilon,$$

where p_j is the unit price of mobile-to-mobile calls and $\delta = \frac{\varepsilon-1}{\varepsilon}$. The maximised benefit accruing to the representative consumer from making calls to other mobiles, w_i^m , is given by substituting (3) into (2), which gives

$$(4) \quad w_{i,j}^m = \rho (a_i)^\varepsilon \left(\frac{\delta}{p_j} \right)^{\varepsilon-1} \varepsilon^{-1}.$$

The number of fixed subscribers is assumed to be constant. As in the mobile-to-mobile case, the representative consumer's utility function for mobile-to-fixed calls is assumed to be of the form

$$(5) \quad u_i(q) = a_i q^{(\varepsilon-1)/\varepsilon},$$

where q is the quantity of mobile-to-fixed call minutes demanded per year by one mobile subscriber and the other parameters are as described above. Note that the assumption of a constant number of fixed subscribers means that the utility function does not need to be multiplied by ρ (or equivalently, the penetration rate is effectively equal to one for fixed subscribers).

The corresponding demand function for mobile-to-fixed calls is

$$(6) \quad q_{i,j}^f = \left(\frac{a_i \delta}{p_j^f} \right)^\varepsilon$$

and the maximised benefit accruing to the consumer is

$$(7) \quad w_{i,j}^f = (a_i)^\varepsilon \left(\frac{\delta}{p_j^f} \right)^{\varepsilon-1} \varepsilon^{-1}$$

where p_j^f is the unit price of mobile-to-fixed calls.

Subscribers to fixed lines are assumed to demand Q minutes of fixed-to-mobile call minutes from each mobile user. The demand function for fixed-to-mobile calls is

$$(8) \quad Q = B_1 - B_2 P$$

where P is the unit price and $B_1, B_2 > 0$ are known parameters.

As discussed above, the representative consumer's benefit from mobile subscription is modeled via a generalisation of the standard Hotelling model to the case of J firms, with the firms arranged around the vertices of a simplex and consumers

distributed uniformly along the edges. Normalising the total distance along the edges of the simplex to 1, and noting that there are $J(J-1)/2$ such intervals, the length L of any single interval is

$$(9) \quad L = 2/J(J-1).$$

To model network benefits we attribute to the position of consumer i located between any two firms a subjective benefit from subscription to either of the two firms. Letting $x_{i \rightarrow j} \in [0, L]$ be a position index measuring the distance between consumer i and firm j , the firm-specific network benefit θ of consumer i can be written

$$(10) \quad \theta_i = \beta_j - tx_{i \rightarrow j}$$

where β_j is the maximum possible benefit to consumer i from subscribing to firm j (corresponding to $x_{i \rightarrow j} = 0$) and $t > 0$ is a parameter determining the rate at which this benefit declines as the consumer moves away from firm j .

The total benefit accruing to consumer i from subscribing to firm j is then the sum of network and call-related benefits

$$(11) \quad U_j(x_i, a_i) = w_{i,j}^m + w_{i,j}^f - r_j + \theta_i$$

$$= \left[\rho \frac{(a_i)^\varepsilon}{\varepsilon} \left(\frac{\delta}{p_j} \right)^{\varepsilon-1} + \frac{(a_i)^\varepsilon}{\varepsilon} \left(\frac{\delta}{p_j^f} \right)^{\varepsilon-1} - r_j \right] + \beta_j - tx_{i \rightarrow j}$$

where r_j is the annual rental rate charged by mobile firm j to each subscriber.

Given the choices of consumers, firms maximise profits with respect to their decision variables (mobile-to-fixed and mobile-to-mobile per-minute prices and annual

rental rates) subject to the prices and rentals of other firms. Revenues accrue to the firms through unit prices and rentals charged, as well as through charges levied on other firms for the termination of calls from other firms. Costs accrue through the costs of originating calls (assumed to be fixed) and the charges levied by other firms for terminating calls.

Table 1: Costs and revenues for mobile firm j

Mnemonic	Description	Classification
p_j	Unit price charged to subscriber i by mobile firm j for call to mobile firm $k \neq j$	Revenue
p_j^f	Unit price charged to subscriber i by mobile firm j for call to fixed firm	Revenue
r_j	Rental charge (non call-related) by mobile firm j to subscriber i	Revenue
A_j	Unit price charged to fixed firm by mobile firm j for terminating calls which originate on the fixed firm	Revenue
c	Unit cost incurred by mobile firm j to originate a call to another firm (either fixed or mobile) Unit cost incurred by mobile firm j to terminate a call from another firm (either fixed or mobile)	Cost
C	Unit cost charged to mobile firm j by fixed firm to terminate a call originated on mobile firm j Unit cost incurred by fixed firm to originate a call made to a mobile firm	Cost
F	Per-customer cost to mobile firm j of non-call service provision	Cost

The unit price charged by mobile firms to other mobile firms for terminating calls is assumed to be set equal to cost c . This means that mobile-to-mobile termination makes no net contribution to mobile firm profits. While this may not be a realistic assumption in practice, it is used to focus on the role of the fixed-to-mobile termination charge. The termination charge set by the fixed-line operator for mobile-to-fixed calls is assumed to be set by regulation at the corresponding termination cost.

Given these assumptions the profit function of firm j , assuming that the fixed-line

operator is non-integrated, is given by

$$(12) \quad \pi_j = n_j \left[(r_j - F) + (A_j - c)Q \right] + \sum_{i=1}^N \left[\rho(p_j - 2c)q_{i,j}^m + (p_j^f - c - C)q_{i,j}^f \right] \cdot I_{\{i \in j\}}$$

where n_j is the number of consumers subscribing to firm j and $I_{\{i \in j\}}$ is an indicator function taking the value 1 if a consumer i subscribes to firm j and zero otherwise. The unit price of fixed-to-mobile calls is set by regulation at $P = C + A + \alpha$ where α is a fixed retail mark-up. This form assumes that higher termination charges get fully reflected in higher fixed-to-mobile prices, a feature consistent with the pricing arrangements in Colombia, as will be discussed.

The market penetration rate is defined as the number of consumers subscribing to mobile firms as a proportion of the total number of consumers

$$(13) \quad \rho = \frac{1}{N} \sum_{j=1}^J n_j$$

3.2 Model solution

Given the decision variables $\mathbf{z} = \{p_1, \dots, p_J, p_1^f, \dots, p_J^f, r_1, \dots, r_J\}$ and model parameters $\{a_{\min}, a_{\max}, t, \beta_1, \dots, \beta_J, \varepsilon, B_1, B_2\}$, solving the model involves firms maximising their profits given the choices of consumers. To perform this optimisation a grid of N points is generated over the space $[a_{\min}, a_{\max}] \times [0, 1]$ to represent the consumers in the model and their attributes (a, x) . The grid is constructed so that the minimum distance d between any pair of consumers in the x -direction is equal to the minimum distance between any pair of consumers in the a -direction, and consumers extend to a distance $d/2$ from the edge of the space.

Each firm's profits, given market shares, prices and rentals, are computed as follows:

For each consumer i and firm j if

$$U_{i,j}(x_i, a_i | \rho, \mathbf{z}) > 0$$

$$U_{i,j}(x_i, a_i | \rho, \mathbf{z}) > U_{i,k}(x_i, a_i | \rho, \mathbf{z})$$

for all firms $k \neq j$ then consumer i is assigned ('subscribes') to firm j . Once this condition has been checked for every consumer $i = 1, \dots, N$, π_j is computed from (12) and the optimisation problem

$$(14) \quad \max_{(p_j, p_j^f, r_j)} [\pi_j | p_{/j}, p_{/j}^f, r_{/j}]$$

is solved for each j until profits are maximised for each firm. Since the profit function depends on ρ , $I_{\{i \in j\}}$ and n_j , which in turn depend on \mathbf{z} through (11), these values have to be determined for each iteration of (14). To do this we define an index variable l (initialised at $l = 1$) and choose an arbitrary starting value for the market penetration rate $\rho(l-1) \in (0,1)$. Then the market shares corresponding to this value of ρ are determined as follows:

(i) For each i and j , if

$$U_{i,j}(x_i, a_i | \rho(l), \mathbf{z}) > 0$$

$$U_{i,j}(x_i, a_i | \rho(l), \mathbf{z}) > U_{i,k}(x_i, a_i | \rho(l), \mathbf{z})$$

for each firm $k \neq j$ then set $I_j(i) = 1$, otherwise set $I_j(i) = 0$.

(ii) For each firm j set

$$n_j(l) = \sum_i I_j(i)$$

and compute the market penetration rate

$$\rho(l) = \frac{1}{N} \sum_{j=1}^J n_j(l)$$

(iii) If $|\rho(l) - \rho(l-1)| > tol$ for some $tol > 0$ (chosen to be 1×10^{-3} in simulations) set $l = l + 1$ and return to (i). Otherwise set $\rho = \rho(l)$ and $n_j = n_j(l)$.

The number of consumers is set at $N = 64,800$. This is to some extent arbitrary, simulation sizes between fifty and one-hundred thousand provide a reasonable trade-off between numerical accuracy and computation time.

4 Model calibration

This section explains the data based on the case of Colombia, and the calibrated benchmark parameter values resulting from the calibration exercise.

4.1 Colombian fixed-to-mobile arrangements

In Colombia, mobile network operators set the retail fixed-to-mobile price (P) and the fixed network operator charges the mobile network operators for the cost of origination. This is different from the arrangements used in European countries, Australia and New Zealand, where fixed operators set the fixed-to-mobile retail price and are charged for mobile termination access (at the termination rate). While the two

arrangements are different from a licensing point of view⁸, they are essentially equivalent for the purpose of this paper. To see this consider the following example:

Assume that, under both arrangements, fixed origination is regulated at C . In the European example, assume that the mobile network operator charges A for mobile termination and the fixed operator charges $P = A + C$. In this way, by choosing A , the mobile network operator also chooses the retail fixed-to-mobile price. In the Colombian example, the mobile network operator chooses the retail fixed-to-mobile price P and pays a (regulated) fixed origination. So by setting a retail fixed-to-mobile price, the mobile network operator implicitly sets a ‘termination charge’ on its network.

4.2 Calibration methodology

Given the N consumers and J firms, costs F , c and C , and the mark-up α , calibration of the model involves choosing values for the parameters $\{a_{\min}, a_{\max}, t, \beta_1, \dots, \beta_J\}$ to ensure that, for our chosen country, the simulated model generates prices, rentals, market shares $n_i / \sum_i n_i$ and market penetration rates ρ observed in practice.⁹

To do this we first compute the (numerical) derivatives of the target variables with respect to the calibrating parameters. Then an iterative scheme is used to find the set of parameters that best match the target variables to the observations. Given the near-linearity of the model, iterative schemes employing a single computation of the Jacobian can be used.

⁸ That is, with respect to who owns the call and who has the commercial freedom to price differentiate.

⁹ These variables are referred to as *target variables*.

4.3 Data for Colombia

To calibrate the model we use annual data on rentals so that demand is measured on an annual basis. The data for the fixed and mobile telephony markets in Colombia are¹⁰:

- $J = 3$ mobile firms, 1 fixed firm (regulated) – these three mobile operators are Colombia Movil, Comcel and Bellsouth (now Telefonica)
- $N = 42.3$ million consumers, 8.4 million of whom own a mobile phone ($\rho = 20$ per cent mobile penetration rate)
- Market shares are $n_1 = 4.75$ million, (56.5 per cent market share), $n_2 = 2.67$ million, (31.8 per cent) and $n_3 = 0.98$ million (11.6 per cent)
- Plausible assumptions for unit costs are $C = \$0.05$ and $c = \$0.10$
- $A = \$0.21$ fixed-to-mobile termination rate for all firms (averaged of current termination charges). This termination rate is computed as a weighted average of fixed-to-mobile retail prices ($\$0.26$) minus the fixed origination costs ($\$0.05$).
- The annual per subscriber cost is set at $F = \$36$. This is based on an estimated fixed cost of $\$3$ per month, which was inferred from the fact that most mobile operators have a minimum spend policy of roughly $\$4$ per month.

Given these data, the calibrated parameter values, using the procedure described in 4.1, are (in rounded values):

- $a_{\min} = 10, a_{\max} = 35$
- $\beta_1 = 670, \beta_2 = 190, \beta_3 = 65$
- $t = 8,000$

For simplicity we report results for the symmetric case – that is, where all three firms are the same size. At a termination charge of $A = \$0.21$ this implies firm-specific parameters of $\beta_1 = \beta_2 = \beta_3 = 215$ to obtain a simulated penetration rate of 20 per cent.

¹⁰ Some of this information is taken from ‘Informe Tercer Trimestre – Julio a Septiembre de 2004’ available at

http://www.mincomunicaciones.gov.co/mincom/src/user_docs/Archivos/Sectorial/InfTrimCelulares.pdf

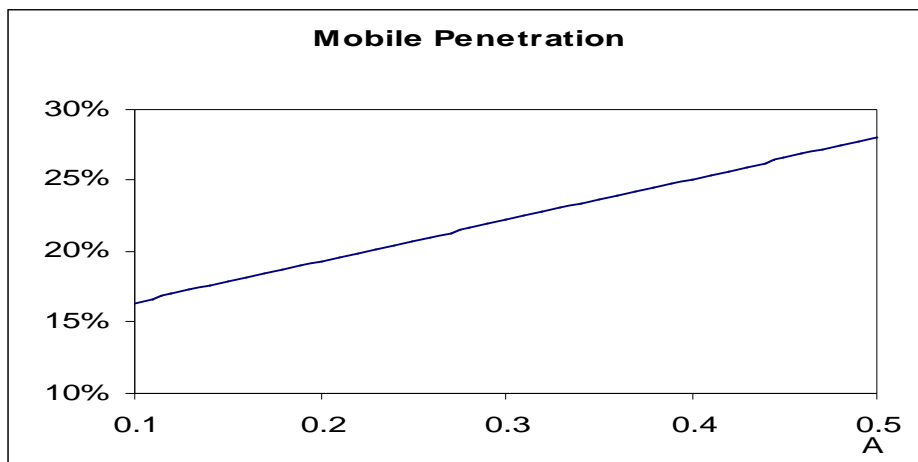
The simulation results in the symmetric case are similar to those obtained for the asymmetric case using the parameter values reported above. The reason for using the symmetric case is that it is more computationally stable for relatively small values of N and hence provides a more robust base case for reporting model results.

5 Welfare analysis

This section shows the impact on welfare of changing termination charges using the Colombia model. We start by just looking at impact on the demand for fixed-to-mobile calls, and on the mobile penetration rate. We then turn to looking at broader measures of welfare. In each case, we consider simulation output using the calibrated parameters for a range of termination rates.

The simulated mobile penetration rate increases approximately linearly from 16.5 per cent to 28 per cent as the fixed-to-mobile termination charge is increased from 10 to 50 cents (Chart 1).

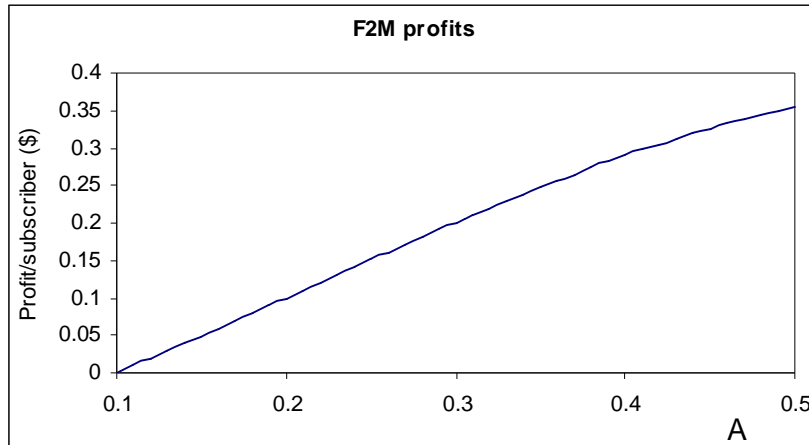
Chart 1: Mobile penetration rate



As the fixed-to-mobile termination charge is increased, total fixed-to-mobile

revenues and profits increase (Chart 2).

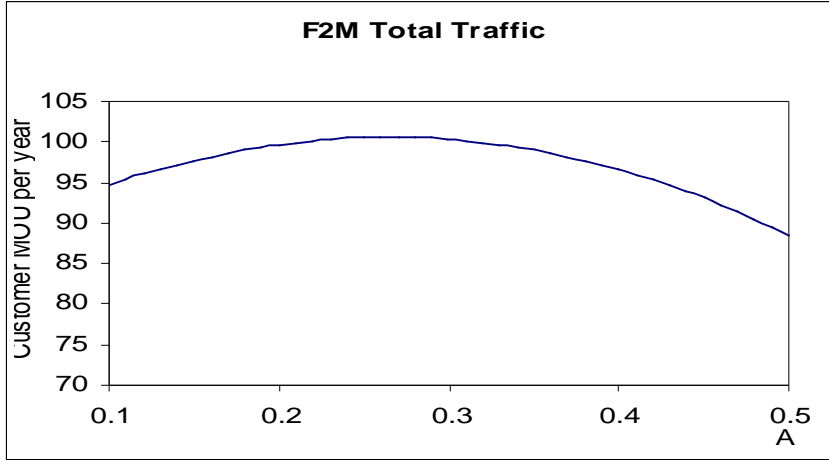
Chart 2: Total fixed-to-mobile profits



Competition amongst mobile firms to collect this lucrative termination revenue drives mobile operators to set low mobile retail prices (some combination of unit prices and rentals) to attract subscribers to their network and thereby collect more termination revenue. This causes more people to subscribe to mobile phones as well as greater usage of these phones, which provides positive spillovers both to fixed-line users and other mobile phone users, since they can now call more people who are away from their fixed line.

The total quantity of fixed-to-mobile traffic increases in the termination charge until it reaches 27 cents, and declines thereafter (Chart 3). The reason for this effect is that initially the increase in mobile penetration causes an increase in total fixed-to-mobile call minutes through the network effect which offsets the (negative) effect of increased fixed-to-mobile prices on the quantity demanded. However eventually the latter effect dominates as prices continue to increase, causing fixed-to-mobile traffic to decline.

Chart 3: Total fixed-to-mobile traffic

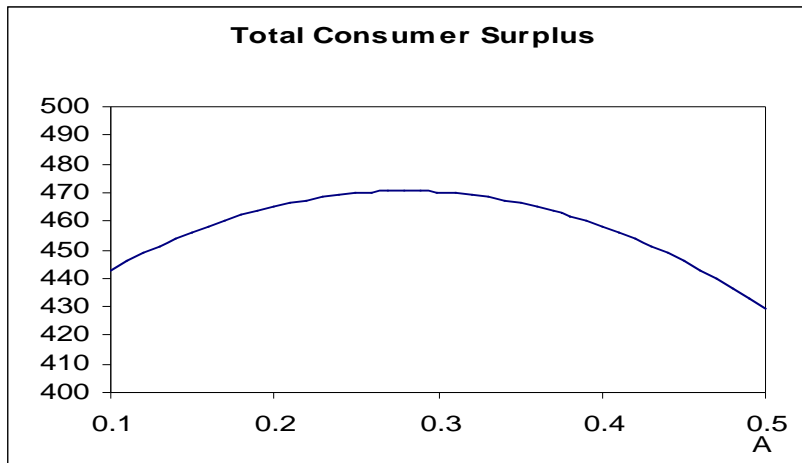


Consumer surplus is defined as the aggregation of each individual's utility from mobile services plus the surplus from fixed-to-mobile calls. In the discrete setting we use, the utility from mobile services is obtained by summing the utilities of the consumers who decide to participate, defined as those for which $I_{\{U>0\}}=1$. The fixed-line surplus is given by the area under the demand curve above the market price P . Summing these two terms we have

$$\begin{aligned}
 (15) \quad CS &= \sum_{i=1}^N U(x_i, a_i) \cdot I_{\{U>0\}} + \left(\sum_{j=1}^J n_j \right) \frac{1}{2} Q(B_1 / B_2 - P) \\
 &= \sum_{i=1}^N U(x_i, a_i) \cdot I_{\{U>0\}} + \frac{1}{2} \left(\sum_{j=1}^J n_j \right) (B_1^2 / B_2 - 2B_1 P + B_2 P^2).
 \end{aligned}$$

Chart 4 shows the variation in consumer surplus with the fixed-to-mobile termination rate.

Chart 4: Total consumer surplus (fixed plus mobile)

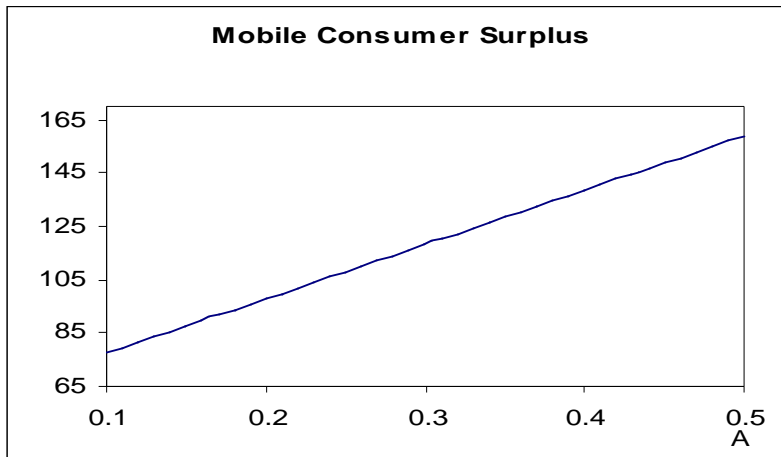


Total surplus to mobile consumers increases with the mobile penetration rate, reflecting the positive impact of higher termination charges (and revenues) being passed back to mobile customers through competition between mobile operators (Chart 5).¹¹ Initially, this increase in termination charges also increases the surplus of fixed-to-mobile callers. This is because, despite higher prices, fixed-to-mobile subscribers can now make more calls (due to more people having mobile phones) and this effect initially dominates. However as termination charges continue to rise, fixed line consumers start to become worse off as a result of higher termination charges and there is a trade-off between fixed-line and mobile customers.¹² The net effect of this trade-off is that total consumer surplus is maximized when termination charges are set at 28 cents.

¹¹ This pass-back is in terms of rentals rather than unit prices.

¹² In practice, mobile customers may also be fixed-line customers, which is why a focus on total consumer surplus is relevant.

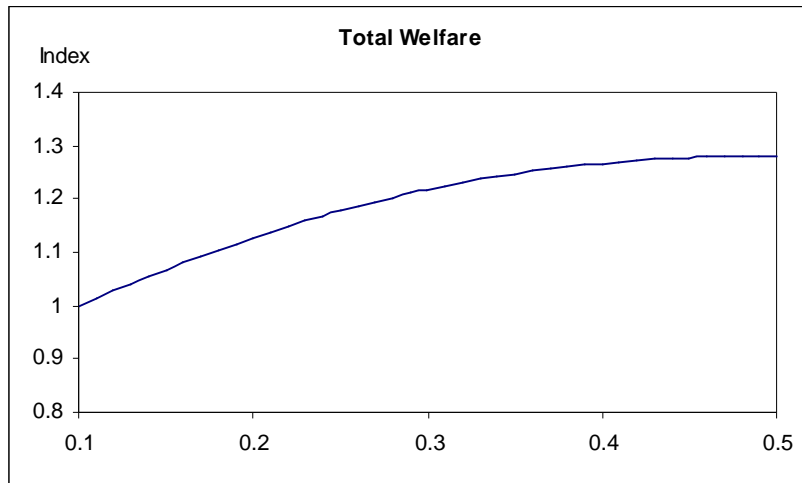
Chart 5: Mobile consumer surplus



The total profits for mobile operators is increasing over the range of termination charges considered, reflecting increased subscription and increased termination revenues. Eventually, higher termination charges lower fixed-to-mobile traffic and profits will peak, which in our setting occurs at a price well above 50 cents. As predicted by economic theory, this is at a level of the termination charge above that which maximizes welfare. Total welfare, the sum of profits and consumer surplus, is shown in Chart 6. Total welfare is maximized at a termination charge of around 48 cents.

More interesting is the result that, contrary to the prediction of economic theory, the current level of termination charges (21 cents) is actually below the level that maximizes mobile operators' joint profits, suggesting firms are not maximizing their joint profits in setting termination charges. Moreover, the current charge is even lower than the level that maximizes welfare. One explanation is that allowing for substitution between fixed and mobile calls implies that the profit maximizing termination charge is actually substantially lower than that predicted by our calibrated model. Alternatively, perhaps the threat of regulatory intervention or the bargaining power of the fixed operator constrain the mobile operators from setting (joint) profit maximizing termination charges.

Chart 6: Total welfare



6 Conclusions and future directions

In this chapter we have analyzed the implications of changing fixed-to-mobile termination charges for a calibrated model of the Colombian mobile market. We did this by extending the existing models that analyze the setting of fixed-to-mobile termination charges to allow for several realistic features. Specifically, we allowed for heterogeneous consumer demand for making calls, which lead firms to set two part tariffs in which unit prices exceeded marginal cost. We also allowed for competition between three mobile operators rather than the more standard duopoly assumption.

Our main new finding is that starting from the current level of termination charges, increasing termination charges has a positive impact on both mobile and fixed-line subscribers, as well as the profits of the industry. This reflects both the low level of mobile penetration to start with (around 20%), and that the current level of termination charges appears to be well below the level that maximizes the mobile operators' joint termination profits. Higher termination charges result in lower mobile rentals, and higher

mobile participation. Under these circumstances, the result is a strong positive spillover to fixed-line users and other mobile phone users, since they can now call more people who are away from their fixed line. We find that starting from current levels, it takes a 33 percent increase in termination charges to maximize consumer surplus, and at least a doubling of termination charges to maximize welfare.

Based on our modeling, calls to regulate lower termination charges from current levels appear to be a step in the wrong direction. For instance, setting termination to cost would result in a 5 per cent reduction in consumer surplus, and a 12 per cent reduction in welfare. Even fixed-to-mobile consumers will be made worse off as their ability to obtain surplus from calling mobile customers is curtailed by the lack of mobile customers. Of course, these results are based on the current low levels of mobile participation in Colombia. As penetration rates approach the high levels seen in many OECD countries, the effects uncovered here will become less important.

In light of our findings, further research could explore the possible reasons for why mobile operators here appear to be setting their termination charges below the level which maximizes their joint profits. Other interesting policy issues to explore include the impact of setting mobile-to-mobile termination charges above cost and the impact of above cost fixed-to-mobile termination rates on the incentives to set mobile-to-mobile termination charges. These issues seem particularly relevant in countries with low mobile penetration rates given that high fixed-to-mobile prices but relatively low mobile-to-mobile prices may further stimulate mobile phone demand as people obtain mobile phones so as to avoid high fixed-to-mobile phone prices.

This last point raises a possible direction for future research, a richer model that

can incorporate substitution between fixed-to-mobile and mobile-to-mobile calls. In this regard, we conclude by outlining what we see as a useful (conceptually at least) framework to model the issue of fixed-to-mobile termination. Consider starting with the assumption that within a given population, people want to call each other randomly (whether they call, and for how long, of course will depend on prices). Then add to this a new feature – assume some fraction of the time people are at home (or at the office), and so can use a landline, and the remainder of the time they are away from home (or office), and so can only make or receive a call on a mobile phone. Then by specifying consumers' utility function for making calls, and adding some heterogeneity across consumers, one can endogenously derive consumers' demand for each type of call (fixed-to-mobile, mobile-to-mobile, mobile-to-fixed) as well as subscription, even if the underlying utility from all types of calls is assumed to be the same.

This has two nice features compared to the existing literature. First, rather than assume some given fixed-to-mobile demand and mobile-to-mobile demand, as we did in this chapter, the demands for the different types of calls are determined endogenously. This becomes important once we allow for substitution possibilities, say between fixed-to-mobile and mobile-to-mobile calls, as it can both reduce the incentive for operators to set high fixed-to-mobile termination charges (due to substitution away from fixed-to-mobile calls), and also increase the welfare benefits of high fixed-to-mobile termination charges (by inducing greater mobile subscription in order to substitute away from fixed-to-mobile calls). Second, from a welfare standpoint, it handles the fact that the people who have to pay the cost of high fixed-to-mobile charges when termination charges are set high, will be some of the same people who benefit from low mobile subscription

charges.

The second extension to the modeling framework would then be to allow the number (or length of) fixed-to-mobile calls to be jointly determined by caller and receiver, taking into account that both callers and receivers obtain some utility from calls (see Jeon et. al., 2004). This would allow us to consider the possibility that networks can charge consumers directly for making and receiving calls, providing a very general framework in which to consider the mobile call termination problem.

Such a framework would allow a more complete picture of the effects of high fixed-to-mobile termination charges to be obtained, and allow issues such as comparisons of receiver pays and caller pays regimes to be addressed at the same time.

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