Mobile termination: what is the "right" charge?*

George Houpis (Frontier Economics)

and

Tommaso M. Valletti (Imperial College London and CEPR)**

March 2004

Abstract

The issue of the regulation of fixed-to-mobile (F2M) termination charges has become increasingly important in the Europe, Australia and Asia under the Calling Party Pays principle. In the absence of any regulation, mobile operators have an incentive to set F2M termination charges "too high", resulting in too few fixed to mobile calls. We show that the setting of the optimal F2M termination charges is quite complex, depending on the significance of network externalities, the intensity of competition in the mobile sector, and the distribution of customer preferences.

JEL: L41, L96

Keywords: Termination charges, network externality

---

* Tommaso Valletti has advised the European Commission on mobile termination and Frontier Economics has acted as advisor to a number of mobile operators on the same issue. The views expressed in this paper are those of the authors alone. We thank Carlo Cambini and Yulia Kossykh for their comments.

** Corresponding author. Tanaka Business School, Imperial College London, Exhibition Road, London SW7 2AZ, UK, Tel. +44-20-7594 9215, Fax +44-20-7823 7685, e-mail t.valletti@ic.ac.uk, http://www.ms.ic.ac.uk/tommaso.

1. Introduction

The issue of the regulation of fixed-to-mobile (F2M) termination charges has become increasingly important in the UK, Europe, Australia and Asia (see Crandall and Sidak, 2004, for a review). Under the Calling Party Pays (CPP) principle, the fixed network subscriber that calls a mobile subscriber has to pay for the call. If the F2M termination charge is set by the mobile operator, and in the absence of any regulation, mobile operators have an incentive to set high F2M termination charges, resulting in too few fixed to mobile calls.

In practice, most regulatory authorities that have considered the issue of regulation of F2M termination charges, have tended to set directly the level (or the rate of change) of F2M charges[1]. Typically, the cost benchmark used to set the level of F2M termination charges is the network LRIC (Long Run Incremental Cost) of mobile termination; an allowance, in the form of a mark-up over LRIC, may also be made to reflect mobile network externalities.

Whilst a considerable effort has been devoted to the derivation of the appropriate cost benchmarks, the economic theory underlying the derivation of the optimal F2M termination charges has been developed more recently, mainly during the recent UK investigation into mobile termination charges. We consider in this paper a general model which allows for mobile network externalities, customer heterogeneity and different intensity of competition in the mobile sector. We show that in such a model, still a "stylized" representation of mobile markets, the setting of the optimal F2M termination charges is quite complex. It requires a regulator to have a significant amount of information on the characteristics of demand and make assumptions about the competitive dynamics of the mobile markets.

The remainder of the paper is organized as follows. In section 2 we review the UK investigation, where a high-profile case motivated most of the recent literature and raised a number of issues. These are addressed in section 3 where we develop an analytical model that incorporates network externalities and consumer heterogeneity. Section 4 reports the numerical results of simulations based on the model of the earlier section. Section 5 concludes by discussing alternative approaches to the setting of mobile termination charges.

2. The UK case

The most recent detailed investigation into the level of mobile termination charges took place in the UK. Oftel decided in September 2001[2] to continue the price control regime for mobile termination charges established in the UK by the Competition Commission in 1998[3]. Oftel considered a range of factors that could restrict such behavior by the mobile

---

1 This has been the approach adopted for example in the most recent decision on the issue in the UK, and is also the approach suggested by the European Regulatory Group. There are some notable exceptions – for example in Australia the ACCC adopted a "tying" remedy approach, where termination charges are "tied" to retail mobile charges.

2 Oftel, *"Review of the Charge Control on Calls to Mobiles"*, September 2001.

3 Oftel first considered the issue of F2M termination charges for calls originating on BT's network in 1997, following a consultation on the price of calling mobile subscribers (Oftel, "*Price of Calls to Mobile Phones*", March 1997) which concluded with concerns about the level of F2M charges. Oftel referred the issue to the Competition Commission (CC), which examined a range of factors that could potentially restrict the level of F2M termination

operators[4] and concluded that none of these could be expected to constrain the level of mobile operators' termination charges to a competitive level. It therefore decided that the appropriate remedy would be a continuation of a price control of mobile termination charges.

The principles underlying Oftel's decision are set out in Armstrong (1997, 2002). Armstrong uses a stylized model of the interaction between fixed and mobile networks[5], to show that under a CPP regime, (unregulated) competing mobile operators would have an incentive to set F2M termination charge at a level that would maximize the profits from F2M termination. The intuition is as follows; consider a situation where there is a fixed telecommunications operator and two perfectly competing mobile operators. Assume also that the mobile-to-fixed termination charge is regulated at cost and the F2M retail price is equal to (perceived) cost, either because of competition, or regulation of fixed retail charges. Assume now that the level of F2M termination charge is at a level below the level that would maximize profits from fixed to mobile termination. Then one mobile operator, by raising the F2M termination charge, would be able to generate additional profits that it could use to lower subscription charges, to attract more customers. The same incentive would exist for the other operator, such that they would be expected to push the F2M termination charge to the monopoly level[6]. In a perfectly competitive (retail) mobile market, these profits would either be used to cover any fixed costs, and/or would be competed away through lower mobile retail subscription prices. Whilst the mobile sector would therefore not be making any excess profits, an inefficiently low number of F2M calls would be made. In the absence of network externalities, Armstrong showed that the welfare maximizing level of the F2M termination charge would be equal to cost.

Armstrong examined also the implication of the existence of network externalities. Network externalities in this context[7], reflect the benefits that accrue to fixed customers from the growth of the mobile subscriber base, as they have more subscribers that they can call. To the extent that these benefits are not fully taken into account when consumers decide whether to become mobile subscribers, it is welfare enhancing to allow mobile operators to earn additional profits from fixed customers that can be used to attract and retain more mobile subscribers. The reason is that in a (perfectly) competitive mobile retail market, any profit generated from mobile termination charges will be competed away through lower mobile subscription charges, leading to an increase in participation to the mobile network. Armstrong showed that, in the presence of network

---

charges and concluded that none of these would be sufficient. The CC therefore imposed a price cap on the level of F2M termination charges of RPI - 9% up to March 2002, applied only to the two largest operators at the time (Vodafone and Cellnet - now O_2).

4 Oftel examined the existence of closed user groups; consumers switching networks so as to reduce the cost of others calling them; substitution of other types of calls; and countervailing power from purchasers of mobile termination.

5 The main assumptions are the existence of three services (mobile-to-fixed calls, fixed-to-mobile calls, and mobile subscription) with corresponding prices, homogeneous demand, a given mobile-to-fixed termination charge (equal to cost) and no utility from or charging for receiving calls.

6 It is possible, in the absence of transparency of F2M prices, for individual operators to push the F2M termination charge even above the monopoly level, as each operator by raising its own F2M termination price would reduce the demand for all F2M calls, thus imposing a negative externality on the other mobile operators (Gans and King, 2000; Wright, 2002).

7 There is another type of externality under a CPP system, resulting from the potential benefit a called party obtains from receiving a call, for which they do not pay – this is called sometimes a "call externality". The focus of this paper is on network externalities.

externalities, the welfare maximizing level of the F2M termination charge, although above cost would always be below the level that mobile operators would set if unregulated – such that the presence of network externalities would not obviate the need for regulation.

Oftel used the framework developed by Armstrong, in order to calculate the appropriate level of termination charges, as a basis for its 2001 price cap proposals. This required Oftel to make assumptions about the values of the elasticity of demand for different services and also required a methodology for reflecting the network externality. Oftel's approach to estimating the allowance above cost for the network externality was to use an assumption about a possible range of the Rohlfs-Griffin factor[8] (RG or externality factor; see Rohlfs, 1979 and Griffin, 1982). The greatest the RG factor the greater, ceteris paribus, the network externality mark-up. Note that although Oftel used this methodology to derive the optimal externality mark-up, the approach implicitly assumes that all other prices (the prices of mobile-to-fixed calls and mobile subscription) would be set to maximize welfare[9]. This approach is equivalent to assuming that all prices would be set by the regulator.

The mobile operators rejected the Oftel proposals, triggering a reference to the Competition Commission. As part of the CC investigation, further work was undertaken on the economic principles underlying the setting of F2M termination charges. In particular, more attention was paid to two key assumptions underlying the derivation of the welfare maximizing F2M termination charge:

- First, the assumption of "perfect competition"; whilst mobile markets are generally considered to be competitive, it is also widely recognized that the actual level of competition does not correspond to the textbook concept of "perfect competition". In this context, the intensity and type of competition may influence the extent to which any additional profits from an externality mark-up get passed on as lower mobile retail charges. This in turn would be expected to affect the welfare maximizing level of the termination charge; and
- Second, and related to the above point, there was a recognition of the need to understand how the welfare maximizing level of the mobile termination charge differs, if mobile operators (rather than a regulator) are free to set the other mobile prices. Under the realistic assumption that customers differ in the pattern of their consumption, with marginal customers consuming less than average, competing mobile operators may favour usage prices, over subscription prices, to "compete" away any given level of profits from the externality mark-up, compared to the case where a regulator would set all charges. This in turn has implications about the welfare maximizing level of the mobile termination charge, which will be different from the level that a regulator would set, if the regulator was setting all prices.

---

8 The RG factor is effectively the ratio of "social value" to "private value" from a subscriber joining a telecommunications network. Rohlfs argued that an RG factor of 1 would imply that all network externalities are internalized. Rohlfs also argued that the maximum value of the RG factor can not exceed 2, which would be the outcome if the value of a calling relationship between two subscribers, was the same for the two subscribers, and none of the network externality was internalized.

9 We will refer to the resulting set of prices and quantities throughout this paper as "second best". The "first best" in the presence of network externalities would require external transfers to the mobile sector, to fund increased participation with no detrimental impact on fixed subscribers.

During the CC investigation, Rohlfs undertook some work for Oftel, to derive updated estimates of the optimal externality mark-up[10]. Rohlfs's model, was an extension of the Oftel model, to allow for mobile-to-mobile traffic, and use of an updated set of elasticity estimates (this provides again a "2nd best" set of prices and quantities). Rohlfs also developed a "principal-agent" model, which recognized that Oftel would only be able to set the F2M termination charge[11], with competing mobile operators then determining the mobile subscription and mobile outgoing call charges. Rohlfs then used his model to simulate the welfare impact of moving from the existing levels of prices, to a set of "2nd best" and "3rd best" prices.

Following a lengthy investigation, the CC concluded in 2003 that a continuation of a price control for mobile termination charges would be necessary. The CC decided that the appropriate cost benchmark was the LRIC of mobile termination, plus a share of fixed and common overheads, and an allowance for mobile network externalities. It proposed that a price control of RPI - X% should apply to the termination charges of all four UK mobile operators[12].

2.1 Other regulatory developments

There are significant variations in the current regulatory approaches to mobile termination across the EU (see Figure 1). However, looking forward, the different approaches across the EU are likely to be harmonised as a result of the EC's New Framework. Under the new EU telecommunications framework, termination of calls to each mobile operator's network has been identified by the European Commission as a separate market, and hence the expectation is that each mobile operator will be found to have Significant Market Power in the market for terminating calls to its own customers.

Jurisdiction(s)	Regulatory approach
Austria, UK	Charges of all mobile operators to be brought down to LRIC
Netherlands, Portugal	Charges of all mobile operators capped in line with EU 'best practice' and European average
Belgium, France, Ireland, Italy, Spain, Sweden	Charges of only operators with SMP in national markets for interconnection to move towards cost-oriented level or in line with other countries
Finland	Generally charges are unregulated except for charges levied by SMP operators on calls originating on other mobile networks or from abroad
Denmark, Germany, Greece, Luxembourg	No terminating tariff controls as no mobile operators found to have SMP

Figure 1: Regulation of mobile termination charges in Europe (Source: *Regulation of mobile call termination charges: international approaches*. CRA, August 2003)

Whilst a number of National Regulatory Authorities have yet to decide on the appropriate remedies under the new EU framework, it is believed that a number will consider some form of more active intervention to set cost oriented F2M termination

---

10 Jeffrey Rohlfs "*A Model of Prices and Costs of Mobile Network Operators*", 22 May 2002, Oftel.

11 We refer to the price/quantity outcomes of such a model as "third best".

12 RPI - 15% (RPI - 14%) for Vodafone and O_2 (Orange and T-Mobile) for each period up to March 2004, March 2005 and March 2006.

charges. Again, some significant effort has already been devoted to the issue of the appropriate cost benchmarks (e.g. European Regulatory Group's (ERG) consultation document on cost benchmarks[13], which builds on earlier work by the Independent Regulators Group) and less so on the derivation of an appropriate level of F2M termination charges in the presence of externalities (there is some limited discussion in the most recent consultation document on remedies[14] by ERG).

In Australia, in July 2001 the ACCC developed pricing principles for GSM termination services. The Commission determined that it would adopt a *retail benchmarking pricing methodology* in its arbitration of access disputes in relation to the termination service. The retail benchmarking approach provides that changes in each mobile carrier's access prices are benchmarked against the retail price movements of its overall mobile package (including access and outgoing calls). The initial starting point for the glide path created by this pricing rule was the lowest current access prices for the mobile origination and termination services in the market.

When the pricing principles were introduced in 2001, the Commission considered retail benchmarking to be the most appropriate methodology for the mobile termination service as it expected that continued competition in the provision of retail mobile telephony services would lead to price decreases for this service. To the extent that retail price decreases could then be translated into the prices set for the mobile termination service, this could help ensure the price of termination was gradually driven down.

However, the Commission "recognised the limitations of the retail benchmarking approach in terms of addressing anti-competitive pricing. It noted that if continued retail price decreases did not eventuate, or if price squeezing was observed in the fixed-to-mobile market, the Commission may need to reconsider its use of the retail benchmarking approach at the time of the next review"[15].

Accordingly, the Commission implemented a monitoring program in conjunction with the retail benchmarking approach, which involved:

1. Monitoring each mobile carrier's retail price movements for the overall mobile package.
2. Monitoring changes in retail prices for F2M calls and access prices for mobile termination to determine whether there is any anti-competitive behavior.

The results of this monitoring to date are concerning in that the retail prices are hardly falling or may have even increased over the three-year period. Therefore, the benchmarking approach has not led to the desirable outcome of lower termination charges. In April 2003 discussion paper, the Commission considered the pros and cons of alternative approaches, including total service LRIC and "retail-minus avoidable costs". The Commission was seeking opinion of the interested parties on whether these methodologies would be appropriate for pricing termination services in the future.

In summary, a number of regulatory authorities in countries using the CPP principle are expected to consider more active intervention for the setting of F2M termination charges in the future. The UK investigation represented a very high-profile case, because of the

---

13 ERG Consultation Document, "*Proposed ERG common position regarding FL-LRIC cost modelling*", July 2003.

14 See Case 4 on mobile termination in Chapter 4 of ERG's "*Consultation Document on a Draft Joint ERG/EC approach on appropriate remedies in the new regulatory framework*", November 2003.

15 "*Mobile services review 2003*", ACCC discussion paper, April 2003.

sums at stake (total termination revenues for the UK mobile industry, according to the latest Oftel market brief[16], were c. £3bn/annum ($ 5.5 bn)) and, more important for our purposes, because of the sophisticated economic analysis that was developed and used during the case. The case was also controversial and some of the economic issues are still outstanding and far from being widely understood.

We develop in section 3 an extended model of the mobile market that reflects some of the key characteristics of this market. We revisit the question of "2nd best" versus "3rd best" FTM charges in the presence of subscription externalities, and we argue that the relationship between them is complex. We then show the potential welfare implications of setting the "wrong" charge, and conclude with a discussion of possible alternative remedies to the direct setting of termination charges.

3. The model

This section presents a model that examines the setting of F2M termination charges when the mobile-to-fixed termination charge is already fixed (set by regulation), in the presence of network externalities. In particular, we want to compare F2M termination charges set by the regulator when it does not regulate other prices (third best), with the case where all mobile prices are set to maximize welfare (second best).

3.1 The basic model

We assume that there is one fixed operator and one mobile operator. The prices of the fixed operator (mobile-to-fixed termination and F2M retail price) are assumed to be set at (perceived) cost, for instance because the incumbent fixed operator is regulated. We also assume that there are no mobile-to-mobile or fixed-to-fixed calls and that customers derive utility when they make calls themselves and not when they receive calls[17].

The regulator maximizes total welfare, which is defined as the sum of mobile and fixed customers consumer surplus and mobile operator's profit (the fixed operator is regulated at cost, therefore, its profit is zero).

The notation we adopt is the following (lower case letters are used for the mobile operator, upper case letters are used for the fixed operator):

- a, A – termination charges of mobile and fixed operators respectively;
- p, P – call prices of mobile and fixed operators respectively;
- (c^O, c^T) and (C^O, C^T) – costs of origination and termination of each call for mobile and fixed operators. Let $c = c^O + C^T$ denote the total marginal cost of a mobile-originated call and terminated on the fixed network; and
- finally, let k denote the fixed cost per mobile subscriber.

There is a unit mass of potential mobile subscribers and a mass N of fixed subscribers. Let $n \leq 1$ denote the number of mobile users that effectively subscribe to the service. The indirect utility of a fixed user from making calls is $V(P)$ per mobile subscriber, with $Q(P) = -\partial V / \partial P$ being the number of calls made per mobile subscriber. This

16 "*Market Information: Mobile Update*", Oftel, October 2003. This is an annualized figure based on figures for Q2 of 2003.

17 See Armstrong (2002) and Wright (2002) for extensions that allow for mobile-to-mobile calls and for call externalities.

formulation reflects the presence of a network externality because the consumer surplus of fixed customers increases when more people subscribe to the mobile network. Aggregate surplus of fixed users and the total number of F2M calls are then:

$$CS_F = NnV(P)$$
$$Q_{FM} = NnQ(P)$$

Mobile users are heterogeneous in their preferences. When a generic customer of type θ pays p per call and a subscription fee of f, his indirect utility is $u = v(p, \theta, N) - f$. It is assumed that indirect utility increases in customer's type, where θ is distributed between $\underline{\theta}$ and $\bar{\theta}$ according to a continuous distribution function $G(\theta)$ with density $g(\theta)$. We make the standard assumption of monotone inverse hazard rate $H(\theta) = [1 - G(\theta)]/g(\theta)$, $H' < 0$. The total number of calls made by a mobile subscriber is $q(p,\theta,N) = -\partial v / \partial p$ [18].

We denote by θ^* the marginal type, defined as:

$v(p, \theta^*, N) - f = 0$.

All consumers with $\theta > \theta^*$ subscribe to the mobile network. Rather than working with p and f, we make a change of variables, concentrating on p and θ^* instead, where f can be retrieved from the above equation.

The total number of mobile subscribers, the total mobile consumer surplus and the total number of M2F calls are then:

$$n = \int_{\theta^*}^{\bar{\theta}} g(\theta)\mathrm{d}\theta = 1 - G(\theta^*)$$

$$CS_M = \int_{\theta^*}^{\bar{\theta}} ug(\theta)\mathrm{d}\theta = \int_{\theta^*}^{\bar{\theta}} [v(p,\theta,N) - v(p,\theta^*,N)]g(\theta)\mathrm{d}\theta$$

$$Q_{MF} = \int_{\theta^*}^{\bar{\theta}} q(p,\theta,N)g(\theta)\mathrm{d}\theta$$

The fixed operator is regulated at cost, it charges $P(a) = C^O + a$ and receives $A = C^T$. Finally, the profit of the mobile operator is

$$\pi = n(f-k) + (p-c)Q_{MF} + (a-c^T)Q_{FM} =$$
$$n[v(p,\theta^*,N) - k] + (p-c)Q_{MF} + (a-c^T)Q_{FM}$$

The problem that a benevolent regulator would solve is then

$$\max_{p,a,\theta^*} W = CS_F + CS_M + \pi$$
$$s.t.\ \pi \geq 0$$

This leads to the following three FOCs:

---

[18] Notice how there are also mobile network externalities; however they do not play a role in the welfare analysis that follows as the number N of fixed users is fixed by assumption.

$$\frac{\partial W}{\partial p} = \int_{\theta^*}^{\bar{\theta}} \left(\frac{\partial v(p,\theta,N)}{\partial p} - \frac{\partial v(p,\theta^*,N)}{\partial p}\right) g(\theta)\mathrm{d}\theta +$$

$$(1+\lambda)\left[n\frac{\partial v(p,\theta^*,N)}{\partial p} + Q_{MF} + (p-c)\frac{\partial Q_{MF}}{\partial p}\right] =$$

(1)

$$-Q_{MF} + nq(p,\theta^*,N) + (1+\lambda)\left[-nq(p,\theta^*,N) + Q_{MF} + (p-c)\frac{\partial Q_{MF}}{\partial p}\right] =$$

$$\lambda\left[Q_{MF} - nq(p,\theta^*,N)\right] + (1+\lambda)(p-c)\frac{\partial Q_{MF}}{\partial p} = 0$$

$$\frac{\partial W}{\partial a} = Nn\frac{\partial V}{\partial a} + (1+\lambda)\left[NnQ + Nn(a-c^T)Q'\right] =$$

(2)

$$Nn\left[\lambda Q + (1+\lambda)(a-c^T)\partial Q/\partial P\right] = 0$$

$$\frac{\partial W}{\partial \theta^*} = -\int_{\theta^*}^{\bar{\theta}} \frac{\partial v(p,\theta^*,N)}{\partial \theta^*} g(\theta)\mathrm{d}\theta + \frac{\partial n}{\partial \theta^*} NV +$$

$$(1+\lambda)\left[\frac{\partial n}{\partial \theta^*}(v(p,\theta^*,N)-k) + (p-c)\frac{\partial Q_{MF}}{\partial \theta^*} + \frac{\partial v(p,\theta^*,N)}{\partial \theta^*} n + (a-c^T)NQ\frac{\partial n}{\partial \theta^*}\right] =$$

(3)

$$(1+\lambda)\left\{\frac{\partial n}{\partial \theta^*}\left[v(p,\theta^*,N) + NV - k + (a-c^T)NQ\right] + (p-c)\frac{\partial Q_{MF}}{\partial \theta^*}\right\}$$

$$-\lambda\left[\frac{\partial n}{\partial \theta^*} NV - \frac{\partial v(p,\theta^*,N)}{\partial \theta^*} n\right] = 0$$

3.2 "1st best"

Assume first there is no budgetary problem ($\lambda = 0$), for instance because the regulator can make costless transfers to the regulated firm. Then from (1), (2) and (3) one gets the 1st best solution:

$$p = c$$

$$a = c^T$$

$$v(c,\theta^*,N) + NV(C^O + c^T) = k$$

The interpretation of these results is very simple: all call prices should be set at marginal cost, and the number of mobile subscribers should be such that the total benefit attached to the marginal type (own benefit + external benefit on fixed users) exactly covers the fixed cost per subscriber. Recalling the definition of marginal type, the last condition implies $f = k - NV$, i.e. the marginal type has to be subsidized. In the absence of fixed transfers to the firm, it is also clear that the 1st best cannot be implemented as the firm would be making losses on each subscriber.

3.3 "2nd best"

Imagine now the firm's budget must be balanced, that is λ is positive and $\pi = 0$.

Eq. (1) says that there is no mark up on calls if consumption of the marginal type is the same as average consumption ($q(\theta^*) = Q_{MF}/n$), otherwise the mark up should be positive ($p > c$) if the consumption of the marginal type is less than average consumption.

Eq. (2) can be re-written as

(4) $$\frac{a^{\text{2nd best}} - c^T}{P} = -\frac{\lambda}{1+\lambda}\frac{1}{\varepsilon_{FM}}$$

i.e. the 2nd best termination charge should allow for a mark up over cost reflecting the elasticity of demand of F2M calls, $\varepsilon_{FM} = \frac{\partial Q}{\partial P}\frac{P}{Q}$, and how tight the budgetary problem is. Notice, however, that the mark up is always lower than the one that would be chosen by an unregulated monopolist (the solution is found by letting λ go to infinity). Lets denote by a^{mon} the latter, $(a^{\text{mon}} - c^T)/P = -1/\varepsilon_{FM}$.

Manipulations of eq. (3) when $\pi = 0$ lead to:

(5) $$(1+\lambda)[\frac{\partial n}{\partial \theta^*}NV + (p-c)(\frac{\partial Q_{MF}}{\partial \theta^*} - \frac{\partial n}{\partial \theta^*}\frac{Q_{MF}}{n})] - \lambda[\frac{\partial n}{\partial \theta^*}NV - \frac{\partial v(p,\theta^*,N)}{\partial \theta^*}n] =$$
$$\frac{\partial n}{\partial \theta^*}NV + \lambda\frac{\partial v(p,\theta^*,N)}{\partial \theta^*}n - (1+\lambda)(p-c)[\frac{Q_{MF}}{n} - \frac{\partial Q_{MF}}{\partial n}]\frac{\partial n}{\partial \theta^*} = 0$$

From the previous expression it can be seen that, if there are margins made on calls, they are used to push down θ^*, i.e. to attract more subscribers.

Alternatively, and recalling the definition of a marginal type, eq. (3) can also be used to obtain the optimal mark up above subscription costs:

(6) $$\frac{f-k}{f} = -\frac{\lambda}{1+\lambda}\frac{1}{\varepsilon_f} - \frac{NV}{(1+\lambda)f} - \frac{(p-c)\frac{\partial Q_{MF}}{\partial n} + (a-c^T)\frac{Q_{MF}}{n}}{f}$$

where $\varepsilon_f = \frac{\partial n}{\partial f}\frac{f}{n}$ is the subscription elasticity with respect to the fixed fee, $\frac{\partial n}{\partial f} = \frac{\partial n}{\partial \theta^*}/\frac{\partial v}{\partial \theta^*}$. Eq. (6) says that the normal mark up that one would expect from a typical Ramsey rule (the first term), is pushed down by the second term and by the third term: profits from call origination and termination are used to keep subscription fees low. Notice how a Ramsey rule emerges here even if there are no common fixed costs to be recovered.

The second term would never be taken into account by a monopolist (when λ tends to infinity the second term vanishes). On the other hand, a monopolist would also use part of the profits made on origination and termination to attract more mobile users as this allows for more F2M calls with resulting higher F2M profits.

We now consider a special case in more detail, in order to be able to say something more about the 2nd best solution. We assume that heterogeneity of type θ enters in an additive way in the indirect utility:

$$v(p,\theta,N) = \tilde{v}(p,N) + \theta$$

With this specification, the number of calls made by a mobile subscriber - once connected - is the same for every type. Differences in types affect only the decision whether or not to subscribe. Hence $Q_{MF} = nq(p,\theta^*,N)$ and from eq. (1) it is easy to see that $p = c$, as with the first best. This price would also be chosen by an unregulated firm. To understand why, imagine by contradiction that the calling price is set above cost. This can be neither welfare- nor profit-maximizing: the price can be decreased down to cost

and at least the same amount could be raised via an equal increase in the fixed fee. This would in fact result in a higher consumer surplus, which is better for welfare (if p is regulated) or could be used by the unregulated firm to push fixed fees even higher.

Using this result and the fact that $n = 1 - G(\theta^*)$, and recalling the definition $H(\theta) = [1 - G(\theta)]/g(\theta)$, eq. (5) simplifies to

$$H(\theta^*)\lambda - NV = 0 \tag{7}$$

What is not clear yet is whether an unregulated firm, who makes no margins on outgoing calls, but maximizes termination profits and passes these profits on to mobile customers via lower subscription fees (see eq. (6)), ends up by attracting more or less customers.

Taking the total differential of eq. (7), and recalling from eq. (4) that a increases with λ, we can write:

$$\frac{\partial \theta^*}{\partial \lambda} = -\frac{H + NQ\dfrac{\partial a}{\partial \lambda}}{\dfrac{\partial H(\theta^*)}{\partial \theta^*}} > 0$$

where we have used the monotonicity property of the hazard rate of the distribution function. Hence we can state, unambiguously, that a monopolist, despite passing termination profits on to mobile customers, would still end up by charging them "too much" and attracting "too few" of them.

For the additive case we can then summarize:

- outgoing mobile prices are equal to marginal costs. This holds true also for an unregulated monopolist;
- termination mark ups are desirable in the 2nd best in order to attract more customers; and
- an unregulated monopolist would set both termination charges and subscription fees too high.

The first result does not carry over to other specifications of heterogeneity. Imagine for instance that θ enters in a multiplicative way in the indirect utility:

$$v(p, \theta, N) = \theta \tilde{v}(p, N)$$

In this case the marginal type makes less calls than infra-marginal types. Hence from eq. (1) it is clear that a mark-up over outgoing calls is now imposed. It is better to distort a bit calling patterns as long as the revenue generated in this way from infra-marginal types who make many calls allows the reduction of other prices. Rewriting eq. (1) as:

$$\lambda[Q_{MF} - nq(p, \theta^*, N) + (p - c)\frac{\partial Q_{MF}}{\partial p}] + (p - c)\frac{\partial Q_{MF}}{\partial p} = 0$$

it is possible to see that while both the regulated and unregulated calling prices include a mark-up, the latter is typically "too" high: the unregulated price is the one that sets equal to zero the first term (the square bracket), while the second term is negative, hence a social planner would want to push the unregulated price to a lower level. The full analytical treatment of the multiplicative case is quite involved, hence we prefer to discuss it with reference to some numerical examples presented below in section 4.

3.4 "3rd best" with a monopoly mobile provider

We now consider the case where the regulator can affect only the choice of the termination rate. This was referred to as the "principal-agent" model in the UK investigation, as suggested by Rohlfs: the principal/regulator can only try to affect the agent/mobile firm choices indirectly via the termination charges but prices charged to the mobile consumer are entirely left to the mobile firm. Hence we now analyze a two-stage game where the regulator first sets *a*, then the monopolist mobile firm sets *p* and *f*.

We concentrate on the case of additive heterogeneity. We have already shown above that even a monopolist firm would set the outgoing calling price equal to cost, $p = c$, on the other hand the monopolist's choice of θ^* (which is equivalent to setting the subscription fee) is:

$$\frac{\partial \pi}{\partial \theta^*} = \frac{\partial n}{\partial \theta^*}[v(p,\theta^*,N) - k + (a - c^T)NQ] + (p-c)\frac{\partial Q_{MF}}{\partial \theta^*} + \frac{\partial v(p,\theta^*,N)}{\partial \theta^*} n = 0$$

that in the additive case simplifies to:

$$\theta^* + \tilde{v}(c,N) - k + \pi^T(a) - H(\theta^*) = 0 \qquad (8)$$

where $\pi^T(a) = (a - c^T)NQ$ is the termination profit per mobile subscriber (this profit is maximized for $a = a^{mon}$).

Since the monopolist maximizes profits, it is clear that *f* will be too high and too few people will subscribe. However from eq. (8) it is also clear that the regulator can try to affect the allocation of subscribers by acting on the access charge. In fact, calling $\theta^*(a)$ the solution implicitly defined by eq. (8), it results:

$$\frac{\partial \theta^*}{\partial a} = \frac{-\partial \pi^T(a)/\partial a}{1 - \partial H/\partial \theta^*} \le 0 \quad \text{for } c < a \le a^{mon} \qquad (9)$$

In the first stage the social planner maximizes welfare subject to the monopolist's pricing behavior. Notice that monopoly power now implies that some extra rents will always accrue to the monopolist, despite access regulation. Hence, in the first stage the social planner solves $\max_a W(a, \theta^*(a))$, leading to:[19]

$$\frac{\partial W}{\partial a} + \frac{\partial W}{\partial \theta^*}\frac{\partial \theta^*(a)}{\partial a} = Nn(a - c^T)\frac{\partial Q}{\partial P} + \frac{\partial n}{\partial \theta^*}\frac{\partial \theta^*}{\partial a}[v(p,\theta^*,N) + NV - k + (a - c^T)NQ] = 0 \qquad (10)$$

The third best solution takes the following form:

$$\frac{a^{3\text{rd best}} - c^T}{P} = \frac{1}{|\varepsilon_{FM}|}\left(-\frac{\partial \theta^*}{\partial a}\right)\frac{1 + NV/H}{Q_{FM}}$$

Departure from marginal costs depend on three multiplicative factors:

- the elasticity of F2M calls. Mark ups are smaller the more elastic demand is;

[19] The observation that the monopolist makes some extra-rents means that in the expression below we can still use eq. (2) and eq. (3) with $\lambda = 0$.

- the extent to which the monopolist transforms higher termination profits into lower subscription fees (the second term on the RHS of the above equation, given by eq. (9)). Mark ups are lower the smaller this effect is;
- a third term that reflects the magnitude of externalities and how elastic the demand for mobile subscription is. The mark up is lower the more inelastic the subscription elasticity, as the elasticity can be written as: $\varepsilon_f = \frac{\partial n}{\partial f}\frac{f}{n} = \frac{-g(\theta^*)(v+\theta^*)}{1-G(\theta^*)} = -\frac{v+\theta^*}{H}$.

From eq. (10) it is clear that the third best solution is above the first best (since when $a = c^T$ then the first term in eq. (10) is zero but the second term is positive, hence $\frac{\partial W}{\partial a}\Big|_{a=c^T} > 0$) and also below the unregulated solution (since when $a = a^{mon}$ the second term is zero – θ^* does not react locally to changes is a – and the first term is negative; hence $\frac{\partial W}{\partial a}\Big|_{a=a^{mon}} < 0$).

The third best solution is also higher than the second best solution. This is because, if the regulator sets $a = a^{2nd\ best}$, then the monopolist would set f too high and attract too few people. Since $a^{2nd\ best} < a^{mon}$, then small increases of a above $a^{2nd\ best}$ would induce the monopolist to pass on some of the termination profits to mobile customers via lower fees (see eq. (9)), and this is welfare improving because of network externalities.

Finally, the subscription fee is obtained from eq. (8): as the monopolist transfers part of the termination rents on to lower fees, it then results that the fixed fee that would be chosen by an unregulated monopolist is actually lower than the third best fee. We can thus conclude:

$$c = p^{1st\ best} = p^{2nd\ best} = p^{3rd\ best} = p^{mon}$$
$$c^T = a^{1st\ best} < a^{2nd\ best} < a^{3rd\ best} < a^{mon}$$
$$f^{1st\ best} < f^{2nd\ best} < f^{mon} < f^{3rd\ best}$$

In summary, the unregulated monopolist would achieve a higher mobile participation than regulated third best, but at a higher overall welfare cost, since the loss of fixed customers welfare from higher F2M termination charges would exceed the benefits from the higher welfare resulting from increased mobile participation.

Our result that the "3rd best" F2M charge is always above the "2nd best", is in contrast to Rohlf's simulations conducted for Oftel during the UK investigation, where he found the opposite. Rohlfs does not present a fully-fledged model, so it is not very easy to interpret his findings. However, our understanding is that the difference comes from the fact that Rohlf's behavioral assumptions in the "principal-agent" model are rather *ad hoc*. He assumes that the mobile firm's objective function includes the *entire* consumer surplus of both fixed and mobile customers, as well as mobile profits. Total consumer surplus and mobile profits have different weights, where a greater weight attributed to consumer surplus is used as a proxy for competition in the mobile market. This implies that the "agent" in his model, has similar objectives as the "principal" in the 2nd best, and the

result that the "3rd best" F2M termination charge is below the "2nd best" comes as a consequence[20].

3.5 "3rd best" with (imperfectly) competitive mobile providers

The last case we consider is how the termination charges should be regulated when mobile customers are potentially supplied by more than one firm. As discussed in the introduction, mobile competition for customers is typically unregulated, and therefore the only instrument at a regulator's disposal is the termination charge.

Our aim in this section to see how the intensity of competition affects the regulation of termination charges. We give analytical results for the additive case and numerical results for the multiplicative case. As before, we study a two-stage game. First the regulator sets a, then competition determines outgoing charges and subscription fees.

Assume first there is perfect competition in the mobile sector. Mobile firms would set outgoing charges equal to costs, while fixed fees would be lowered until firms just break even. Any termination profit is entirely passed on to customers. In the additive case, if competition is perfect then the regulator can set termination charges equal to the second best charges determined in section 3.3. This is because firms themselves already choose $p = p^{2\text{nd best}} = c$, and if a is set to the level defined by eq. (4), then also f would be set at the second best (since in the 2nd best the firm just breaks even).

What happens if competition is less than perfect? To facilitate comparisons with the previous section[21] we continue to assume that all mobile firms offer the same good, but competition is imperfect in an "hybrid" Cournot fashion. Two prices have to be determined by the competitive process: the price for outgoing calls and fixed subscription fees. To accommodate this, we assume that firms first compete over prices in order to maximize the utility of the customers they serve (for a given size of the mobile market), and then decide how many users to attract: this last aspect represents the Cournot feature that allows to determine the fixed subscription fee.

As calling surplus is once again maximized for $p = c$, we get that firms would always set the 1st best calling price. Imagine now there are m mobile firms that decide over how many customers to attract. Since

$$\sum_i^m n_i = n = 1 - G(\theta^*)$$

$$f = v(p, \theta^*, N)$$

---

20 Rohlf's model is quite complex as it aims at capturing many details of the actual UK market. He does not states explicitly what timing he assumes in setting the various prices and he solves a system of simultaneous equations where the mobile firm is constrained by the regulator and the regulator is constrained by the firm's behaviour. Recall that the regulator's objective is to maximize $W = CS + (1 + \lambda)\pi$ with respect to a, where $CS = CS_F + CS_M$ and λ is the multiplier of the firm's budget constraint. Rohlfs assumes that the mobile firm maximizes $kCS + (1 - k)\pi$ with respect to mobile prices, which is equivalent to the maximization of $CS + \mu\pi$ where μ is given by $\mu = (1 - k)/k$. Imagine the "principal" and the "agent" set their respective prices simultaneously. Hence, if the weight attributed to total consumer surplus is high enough, then the firm will want to set low prices. However, as it cannot make losses, it will have to break even: the "2nd" best and the "3rd" best then coincide, since if the regulator sets $a^{2\text{nd best}}$, there is only one $f = f^{2\text{nd best}}$ that ensures $\pi = 0$. If the firm, on the other hand puts less weight on CS, it will then choose $f > f^{2\text{nd best}}$ and the regulator will set $a < a^{2\text{nd best}}$ as there is no feedback between the subscription charge and the F2M termination charge.

21 We cannot introduce features of horizontal differentiation (e.g. a Hotelling model where two mobile firms are located at the opposite ends of a unit line over which mobile customers are distributed) since these extra features are not present in our benchmark analysis and comparisons would not be valid.

The profit of firm i that set $p = c$ and attracts n_i customers is

$$\pi = n_i[(f-k)+(a-c^T)NQ] = n_i[v(c,\theta^*(n_i,n_{-i}),N)-k+(a-c^T)NQ]$$

where $\partial\theta^*/\partial n_i = -1/g(\theta^*)$. The FOC for firm i is:

$$v(c,\theta^*(n_i,n_{-i}),N)-k+\pi^T(a)+n_i\frac{\partial v}{\partial\theta^*}\frac{\partial\theta^*}{\partial n_i}=0$$

that, for the additive specification, simplifies in a symmetric equilibrium to:

(11) $$\theta^*+\tilde{v}(c,N)-k+\pi^T(a)-H(\theta^*)/m=0$$

Eq. (11) reduces to eq. (8) when m =1. The analysis we have conducted in the previous section then goes unaltered, with the difference that now the change in the number of customers depend on the number of competing mobile firms:

(12) $$\frac{\partial\theta^*}{\partial a}=\frac{-\partial\pi^T(a)/\partial a}{1-\frac{\partial H}{\partial\theta^*}\frac{1}{m}}\le 0$$

In particular, compared to eq. (9), it can be seen that the termination "pass-through" increases with competition (proxied by m). The expression for the 3rd best case then looks exactly the same as the one in the last section 3.4 but implies that the optimal level of a is actually going to be lower: as more termination profits are passed on to customers, it is not necessary to allow as big a mark-up as before.

4. Simulations of the model

4.1 Additive

In table 1 below we put numerical values obtained by solving the model for the additive specification of preferences. In particular θ is assumed to be distributed uniformly between 0 and 1 and demands from/to fixed customers are assumed to be linear, generated by the following indirect utilities: $V(P) = (1-P)^2/2$, $\tilde{v}(p,N) = N(1-p)^2/2$.

The numerical results confirm the analytical findings. We point again to the fact that an unregulated monopolist ends up attracting more mobile subscribers n than a (3rd best) regulated monopolist: the former makes monopoly profits over termination and attracts more mobile subscribers. Mobile customers are then better off in the former case. Of course, as overall welfare also takes into account fixed subscribers, the aggregate welfare is higher in the latter situation.

	2nd best	Unregulated	3rd best (monopoly)	3rd best (Cournot duopoly)	LRIC (monopoly)	LRIC (Cournot duopoly)
a	0.31	0.55	0.38	0.36	0.1	0.1
$n = 1-\theta^*$	0.55	0.30	0.29	0.38	0.20	0.27
Welfare	0.28	0.17	0.18	0.22	0.14	0.18

Table 1 - Parameter values: $N = 2$, $c = 0.1$, $c^T = 0.1$, $C^O = 0$, $k = 1$

As indicated in the introduction, some regulators have been examining closely the case for mobile termination charges being set equal to cost (LRIC), typically over a period of time. In the last two columns of the table we show the participation and welfare results of the simulation if the regulator sets the termination charge at cost (1st best). As indicated in the table, both participation and total welfare in this case would be lower than the corresponding third best results – with the welfare reduction ranging from 22% in the monopoly case, to 18% in the Cournot duopoly case.

4.2 Multiplicative

We finally turn to a numerical discussion of the multiplicative case. We take the case where $v(p, \theta, N) = \theta\tilde{v}(p, N)$, and $\tilde{v}(p, N) = N(1-p)^2/2$ and θ is distributed uniformly between 0 and 1.

	2nd best	Unregulated	3rd best (monopoly)	3rd best (Cournot duopoly)	LRIC (monopoly)	LRIC (Cournot duopoly)
a	0.33	0.55	0.395	0.39	0.1	0.1
p	0.31	0.35	0.33	0.10	0.19	0.1
$n = 1 - \theta^*$	0.93	0.56	0.51	0.55	0.21	0.26
Welfare	0.62	0.36	0.40	0.45	0.21	0.26

Table 2 - Parameter values: as in Table 1, with the exception of $k = 0.5$

Table 2 presents illustrates some interesting results. First of all, regulation of access makes a 3rd best monopoly F2M termination charge virtually indistinguishable from a 3rd best Cournot duopoly charge (4th and 5th columns). The reason is that a monopolist still charges too high fixed fees and a substantial termination mark up is thus needed (as a monopolist would not pass a lot of it on to customers). However, the 3rd best monopolist is also making revenues on outgoing calls as it is not challenged by any rival. Again, some of these profits are passed on to customers. On the other hand, in the Cournot case, there is competition for customers. We have assumed that this translates in very tough competition over calls: calling surplus is still maximized when $p = c$ and no profits are made on calls. Hence the regulator, in order to induce a better market coverage, must allow for a substantial termination mark up. This is the only side where subsidies can come from. As it can be seen from the table, the difference between the two situations become negligible in terms of the optimal $a^{3\text{rd best}}$.

Secondly, we can confirm that, as in the additive case, an unregulated monopolist expands the mobile subscription market more than a regulated monopolist. In the numerical example reported above, even Cournot duopolists cover less of the market than an unregulated firm.

Thirdly, notice that while the welfare ranking is always as predicted (Unregulated < Monopoly 3rd best < Cournot 3rd best < 2nd best), the comparison of *relative* prices is quite intricate. In the Cournot multiplicative example, firms choose the 1st best prices over outgoing calls, and this implies that the regulator needs to allow a significant mark-up over the 2nd best F2M charge. In a sense, competition is too intense on outgoing prices as no rents remain there.

Fourthly, notice that in both our analytical results and in the numerical ones, the "2nd best" F2M termination charge is always lower than any "3rd best" termination charge.

In the last two columns of the table we have shown again the participation and welfare results of the simulation if the regulator sets the termination charge at cost (1st best). Note that in this multiplicative case, the reduction in welfare is even more marked. In particular, it can even result that overall welfare is higher with an unregulated firm than with competing firms regulated at cost (LRIC) over termination.

In summary, a proper regulation of F2M termination charges is quite a complicated task and the inter-relationships between the different pricing choices and the scope of regulatory intervention are not obvious at all. In addition to the costs of mobile termination, the welfare maximizing termination charge will need to reflect:

- the assumptions made about the level of competition in the (retail) mobile market;
- whether the regulator sets only F2M termination charges, as is the broad expectation, or whether they have the power to set retail mobile charges;
- the assumptions made about the way in which demand differs between different types of customers; and
- the significance of any (un-internalized) network externalities.

5. Remedies and concluding remarks

We showed in the previous sections of this paper that the calculation of the appropriate level of the welfare maximizing F2M termination charge by a regulator, under the realistic assumptions of network externalities and heterogeneous demand, is quite complex. In principle, if the regulator had at its disposal all the relevant cost and demand information the highest level of total welfare would be achieved by setting directly all the prices. This does not happen in practice as regulators let the mobile firms choose retail prices and eventually intervene only on the setting of F2M termination charges. We also showed, using an illustrative example that the setting of the termination charge at the "wrong" level can have serious welfare implications. We examine in this section, possible alternative remedies to the direct setting of F2M termination charges by a regulator[22].

The first potential remedy is to employ some form of "yardstick" approach, where the rate of change of the F2M termination charge is linked to the rate of change of prices of some other services that would reflect the level of cost changes in the mobile industry[23]. One possible benchmark is a basket of tariffs of retail mobile services, which, if set in a competitive market, should reflect changes in the underlying costs of providing mobile services. As discussed earlier, this approach has been adopted by the ACCC in Australia. The main concern with this type of remedy is that it may lead to a "dampening" of competition in the retail market, as any reduction in a mobile operator's retail mobile tariffs would also reduce its F2M termination revenues. Calculating the appropriate benchmark in practice, and deciding what should be included and excluded from the basket may also raise difficulties.

---

22 This section draws in part on a paper written by T. Valletti for the European Commission (Valletti, 2003) and some work by D. Elliott and G. Houpis (Elliott and Houpis, 2002), on the use of bilateral negotiations as a potential remedy for mobile-to-mobile termination charges.

23 This approach also requires a regulator to decide what the starting level of termination charges should be – hence it does not obviate the need for a regulator to calculate the welfare maximizing starting level of charges.

An alternative benchmark is to tie F2M termination charges of one operator to the average of call prices of the *other* mobile operators. This reduces the "competition dampening" effect of the earlier benchmark, but re-instates the need to calculate the optimal tying relationship between the F2M termination charge and the prices of calls of other operators.

An alternative remedy, which goes to the heart of the problem, is to switch from a Calling Party Pays principle to a Receiving Party Pays (RPP) principle[24]. As subscribers receiving calls would be charged for them, they would be likely to be more sensitive to the price of receiving calls. Hence competition between mobile operators for mobile subscribers, could be expected to exert pressure on termination charges. The main drawback with this remedy is that it may provide incentives to mobile subscribers for "sub-optimal" use of their phones – for example through switching on a mobile phone only when the mobile subscriber wants to make a call, or call screening. This has been argued is one of the reasons why mobile penetration in the US, which has used RPP, may have been slower to develop than in Europe, which has used CPP. The introduction of such a remedy would therefore require careful consideration of the wider implications. Furthermore, it is possible that such a remedy could only be introduced for all types of call, which would in turn raise wider issues about the usage of both fixed and mobile telephones.

Rather than imposing RPP by regulatory fiat, an alternative solution is to adopt a "bill-and-keep" system, i.e. providing termination free of charge. This remedy is very extreme, but has the immediate benefit of savings on transaction and measurement costs. Moreover, bill-and-keep has also an economic justification in the presence of calling externalities (DeGraba, 2002). A bill-and-keep remedy is related to RPP since it allows mobile operators to charge customers directly to receive calls (if they want to recover termination costs), without having to mandate this pricing structure. In a sense, RPP could arise endogenously as a response to a bill-and-keep system. The obvious downside is that a bill-and-keep remedy does not address the network externality problem. However, the investigation of such a remedy when applied to the *entire* telecommunications sector (both fixed and mobile) has some merit, as it is a structural remedy that would allow the abandonment of continuous and information intensive regulation of a micro-management type.

Another set of remedies that has been examined is the so called "technological solutions" – these aim to use some form of a technology-based solution, to allow a mobile subscriber to have a different operator deliver incoming calls from the one to which he/she subscribes for outgoing calls. There are two issues with these solutions: first, the technical feasibility itself has been questioned, with the associated issue of the significance of transaction/switching costs. It seems that this problem, is mainly a software problem that could be solved. Secondly, and more importantly, such solutions do not remove the fundamental issue of CPP – namely that the mobile subscriber does not pay for received calls, and hence is not expected to be very sensitive to the price of being called. It is true however that a lower price for receiving calls would be expected to increase the average number of calls received, and to the extent that these confer some benefit to the called mobile party, increase the overall welfare of the mobile subscriber. If such an effect was significant, then a technology-based solution could increase the likelihood of termination charges being set at the competitive level.

---

[24] Mobile subscribers pay for the full cost of receiving a call, or part of the cost. RPP is the pricing principle adopted in the US, see Sidak and Crandall (2004).

A final set of remedies, relies on "countervailing" power between two negotiating parties, and would consist in the obligation for operators to engage in bilateral negotiations to set the termination charges they would pay to each other. This remedy has been advocated more strongly for the setting of mobile-to-mobile termination charges, because (a) the economic literature that has been developed so far, with broadly supportive results for such a remedy, has been applied predominantly to the setting of termination charges between competing operators[25] and (b) the interconnection balances between mobile operators are often broadly in balance, which would be expected to make negotiations for the charge less "sticky". In view of the reduced need for intrusive and continued regulation that such a remedy would imply, the basic principles that make such a remedy attractive between mobile operators, would merit again further research, to establish their applicability between fixed and mobile operators.

Bibliography

Mark Armstrong, 1997, "Mobile Telephony in the UK", Regulation Initiative Working Paper Series, Paper 15, London Business School.

Mark Armstrong, 2002, "The theory of Access Pricing and Interconnection", Chapter 8 in *Handbook of Telecommunications Economics*, Vol. 1, Martin Cave et al. (editors), North-Holland.

Patrick DeGraba, 2002, "Central Office Bill and Keep as a Unified Inter-carrier Compensation Regime", *Yale Journal on Regulation*, 19, 37-84.

Dan Elliott & George Houpis, 2002, "The Setting of Termination Charges between Mobile Operators: Is Regulation Necessary?", Frontier Working Paper.

Joshua Gans & Steven King, 2000, "Mobile network competition, consumer ignorance and fixed-to-mobile call prices", *Information Economics & Policy*, 12, 301-327.

James Griffin, 1982, "The Welfare Implications of Externalities and Price Elasticities for Telecommunications Pricing", *Review of Economics and Statistics*, 64, 59-66.

Jeffrey Rohlfs, 1979, "Economically Efficient Bell-System Pricing", Bell Laboratory Discussion Paper 138.

J. Gregory Sidak & Robert W. Crandall, 2004, "Should Regulators Set Rates to Terminate Calls on Mobile Networks?", *Yale Journal on Regulation*, 21.

Tommaso Valletti, 2003, "Access services to public mobile networks", report prepared for the European Commission, Brussels.

Ingo Vogelsang, 2003, "Price Regulation of Access to Telecommunications Networks", *Journal of Economic Literature*, 41, 830-62.

Julian Wright, 2002, "Access Pricing under Competition: An Application to Cellular Networks", *Journal of Industrial Economics*, 50, 289-315.

[25] See the excellent surveys on two-way access charges by Armstrong (2002) and Vogelsang (2003).