Network-Based Price Discrimination and 'Bill-and-Keep' vs. 'Cost-Based' Regulation of Mobile Termination Rates*

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Abstract

This paper surveys the recent literature on competition between mobile networks in the presence of call externalities and network effects. It argues that the regulation of mobile termination rates based on fully allocated costs, or "long-run incremental cost plus," exacerbates the network effects associated with "tariff-mediated network externalities," by increasing mobile networks' on-net/off-net price differentials. This reduces welfare and acts as a barrier to growth for smaller networks and new entrants. The paper argues for the adoption of "bill-and-keep" for mobile termination rates, and responds to recent theoretical arguments which suggest that such a move might harm mobile subscribers.

KEYWORDS: mobile termination rates, regulation, bill-and-keep, call externalities, network effects

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1 Introduction

European regulatory authorities have recently been debating the merits and demerits of alternative approaches to regulating mobile call termination rates (MTRs). MTRs are the charges that mobile firms levy on fixed networks and other mobile operators for completing, or "terminating", calls on their networks. According to the widely-accepted theory, while downstream competition between mobile networks to attract new customers may be fierce, in the absence of regulation they will still charge excessive prices to other networks for terminating calls to their subscribers. Concerns about mobile call termination being a "bottleneck" service, and a history of high termination charges, have led to the regulation of MTRs in every country in the European Union, and in numerous other countries around the world.[1]

Until now, the approach to regulating MTRs adopted by most regulatory authorities in Europe has been to allow for total cost recovery, based on fully allocated cost models. In the UK, for example, Ofcom regulates the termination charges of the five mobile operators at "long-run incremental cost plus" (LRIC+).[2] Ofcom treats fixed-to-mobile and mobile-to-mobile termination charges symmetrically (i.e. the regulated prices for the two services are set at the same level), and uses a detailed cost model to estimate LRIC+ by allocating the fixed and common costs of a hypothetical efficient network operator over mobile retail and wholesale services.[3]

The main rationale for the regulation of MTRs to date has been to prevent a welfare-reducing distortion in the structure of prices, under which profits from the exploitation of monopoly power in fixed-to-mobile call termination are used to subsidize subscriber acquisition costs. This issue is typically discussed in terms of the "waterbed effect", whereby a reduction (or increase) in termination charges leads to a corresponding increase (or reduction) in

[1] See Armstrong (2002, Section 3.1), Wright (2002a) and Armstrong and Wright (2009a) for the standard theory. The characterization of mobile call termination as a monopoly or "bottleneck" service assumes that mobile operators can make take-it-or-leave-it offers to fixed-line operators and to each other, which is typically justified by reference to various interconnectivity obligations. Binmore and Harbord (2005) question this assumption, and provide an analysis of mobile call termination instead as a bilateral-monopoly bargaining problem. See also Armstrong and Wright (2007, Section 3.5).

[2] Ofcom is frequently cited as being the leading European regulatory authority in the field, so much of our detailed discussion will focus on regulatory practice in the UK. Few, if any, other European regulatory authorities employ cost models as detailed as Ofcom's.

[3] See Ofcom (2007a, Annex 5), especially paragraphs 5.11-5.19.

subscription charges to consumers.[4] Indeed, Ofcom's estimates of the welfare benefits of regulation are exclusively concerned with correcting this inefficiency in the structure of prices, which it believes leads to over-consumption of mobile retail services and under-consumption of fixed network services (Ofcom, 2007a, pp. 101-102; 387-395).[5]

This approach to regulating MTRs has been increasingly called into question, however, by a growing body of economic literature which highlights the two-sided nature of mobile interconnection markets, and the significant role that call externalities play in the analysis of competition, equilibrium pricing, and entry in these markets. Impetus for change has also come from the experiences of new entrant networks in many European countries, which have struggled to gain market share in the face of high MTRs, and the significant levels of on-net/off-net price discrimination adopted by incumbent mobile network operators (MNOs).[6]

In May 2009, the European Commission (EC, 2009a) issued a *Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU* which sets out its views on how national regulators in Europe, such as Ofcom, should approach this issue in future. The Commission's *Recommendation* and accompanying documents (EC, 2009b; 2009c) reflect much of this new economic thinking and experience, and propose dramatic reductions in MTRs to reflect the actual incremental costs of providing voice call termination services to third parties.[7] In light of the EC *Recommendation*, Ofcom has recently produced a consultation document (Ofcom, 2009) which broadly reconsiders the pros and cons of a number of alternative approaches to regulating MTRs, including setting MTRs at zero, i.e. bill-and-keep.[8]

[4] See Ofcom (2006, pp. 77-85); Ofcom (2007a, pp. 101-115); and Armstrong and Wright (2009a, pp. F284-285). Genakos and Valletti (2007) present some empirical evidence on the strength of the waterbed effect in twenty countries.

[5] Ofcom's welfare analysis assumes a single mobile network and a single fixed network. So the effects of regulation on mobile-to-mobile prices and competition play no part in its assessment.

[6] See the European "mobile challengers'" web page for some industry views on these issues (www.mobilechallengers.eu).

[7] This reduction is to be implemented by no longer allowing costs which are common between services to be recovered from regulated termination charges. According to the Commission, this could result in a decrease in average MTRs in Europe from approximately 8.55 euro cents per minute at present, to 2.5 euro cents per minute or less by 2012. While the Commission's recommendation also deals with termination rates on fixed networks, mobile termination rates are typically ten times higher than fixed termination rates in Europe (the latter ranging from 0.57 to 1.13 euro cents per minute), and so have been of much less concern.

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We argue in this paper that the traditional approach to regulating MTRs, as described above, is flawed for a number of reasons, and that — by distorting retail pricing incentives in the mobile market — may have been doing as much harm as good. Both the recent theoretical literature, and the available empirical evidence, provide broad support for the approach recently adopted by the European Commission, and suggest that even more radical change may be called for.

A first simple point, which has been made elsewhere,[9] is that even in the absence of call externalities and the consequent strategic pricing effects, the regulation of per minute mobile termination charges should in principle be based on marginal costs, and not on fully-allocated costs, as estimated by Ofcom's LRIC+ model for example. Very few, if any, mobile telecommunications costs are traffic-sensitive, but they are nevertheless recovered on a traffic-sensitive basis under the traditional regulatory approach. To the extent that regulated termination rates represent fixed costs that are recovered on a per-minute basis, they act to inefficiently increase retail call charges and reduce the number of calls made to mobile networks.

Some fairly compelling evidence for this comes from the fact that mobile operators in Europe frequently set prices for on-net calls — i.e. calls originating and terminating on their own networks — much lower than regulatory estimates of their termination costs. For example, Ofcom's estimates of LRIC+ for the four largest UK operators in 2006 all exceeded 5.5 pence per minute, whereas the average price of on-net calls in 2006 was reported to be 3.5 pence per minute (Ofcom, 2007b, Figure 4.40). Similarly, the Portuguese regulator (Anacom, 2007) estimated "avoidable" termination costs in Portugal of 3.6 euro cents per minute from observations of on-net call prices, compared to the then-regulated rate of 11 euro cents per minute.[10]

[8] The UK's Competition Commission was asked to consider whether Ofcom should have imposed bill-and-keep on mobile operators following Hutchison 3G's appeal of Ofcom's 2007 MTR determination (in Ofcom, 2007). The Commission's panel of economists was prevented by the Competition Appeal Tribunal, however, from considering any arguments in favor of bill-and-keep which depended upon evidence concerning the marginal costs of termination on mobile networks, or the relationship between MTRs and retail prices, specifically network-based price discrimination. Despite this rather bizarre prohibition by the Tribunal, the Commission nevertheless carried out a limited investigation into the economic issues, and not surprisingly found the evidence insufficient to overturn Ofcom's determination on this point. See Competition Commission (2009, Section 14).

[9] See, for example, Quigley and Vogelsang (2003), DeGraba (2003), and Calzada (2007).

[10] The French regulator Arcep (2007), Chapter 4 and pp. 81-82, has reached similar

From first principles, a more efficient structure of prices would regulate per-minute termination charges at marginal cost, but have networks contribute to each others' fixed costs via capacity charges. If, as seems likely, marginal termination costs are near zero,[11] and capacity charges can be expected to net out, a better regulatory policy would be "bill-and-keep", under which reciprocal termination charges are set equal to zero. Quigley and Vogelsang (2003), for example, have argued that, "*capacity-based interconnection charges would be ideal, because they would correctly reflect the costs incurred by the networks*," and noted that, "*bill and keep is like a two-part tariff in access charges: the fixed fee equals the own-network costs for termination of the call generated by the other network, while the variable fee is zero.*"[12]

Our second point, which is the focus of this paper, is that European regulatory policy to date has been based on an incomplete understanding of competitive interaction in mobile markets in the presence of receiver benefits, or call externalities.[13] As recently observed by Hermalin and Katz (2009, p. 30), "*the existence of receiver benefits fundamentally changes the analysis of interconnection charges.*" Rather than the traditional focus on how the terminating network's costs should be recovered from the sender, the key economic issue becomes how prices should be set to recover mobile networks' costs in a way that efficiently internalizes the two-sided benefits.[14] As shown by DeGraba (2003), Hermalin and Katz (2009) and others, this typically entails call prices less than the marginal cost of making a call and, even in the absence of strategic effects (which are discussed immediately below), implies that welfare-maximizing MTRs will be (weakly) less than the marginal cost, and frequently less than zero.

Efficient pricing on mobile networks thus requires call prices below mar-

conclusions. Further evidence on on-net prices versus regulated MTRs is presented in Section 3.2 below.

[11] Ofcom (2009, Annex 9, para A1.33) studies mobile retail call charges in the United States and concludes that "*what we observe from these retail tariffs seems to suggest that the perceived per minute cost is zero or close to zero.*"

[12] Armstrong and Wright (2009a, p. F285) suggest another reason for excluding fixed and common costs from regulated MTRs in competitive mobile markets. In the presence of strong "waterbed" effects, high termination rates will not provide mobile operators with any contribution towards their fixed or common costs, but rather be dissipated in competition to attract new subscribers. Hence '*in this environment, setting high termination charges in an attempt to allow for fixed and common cost recovery is likely to be a flawed policy.*'

[13] Call externalities arise from the fact that although both the sender and the receiver of a call benefit from it, under a "Calling Party Network Pays" (CPNP) regime only the sending party is charged for it.

[14] See also Hermalin and Katz (2004).

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ginal cost, and, assuming that marginal termination costs are the same across networks, equal on-net and off-net call charges. European mobile operators typically set large price differentials for on-net and off-net calls, however, with the latter far exceeding any reasonable estimates of marginal calling costs.[15] The economic rationale for this form of network-based price discrimination has been the subject of a number of recent papers. Jeon *et al.* (2004), Armstrong and Wright (2009b), Berger (2004) (2005) and Hoernig (2007) analyze the impact of *call externalities* and *network effects* on inter-network competition and equilibrium pricing in mobile markets. A key insight of this literature is that mobile networks' incentives to implement on-net/off-net price differentials derive from:

- high mobile-to-mobile termination charges which exceed marginal termination costs; and
- a strategic motive to reduce the number of calls that subscribers on rival networks receive, reducing the attractiveness of rival networks, and hence their ability to compete.

Therefore, high MTRs, coupled with mobile networks' strategic pricing incentives created by call externalities, result in an inefficient structure of prices which reduces allocative efficiency in mobile markets, and overall economic welfare.

Network-based price discrimination results not only in deadweight efficiency losses, but, as discussed in Armstrong and Wright (2009b), Hoernig (2007), Calzada and Valletti (2007), Lopez and Rey (2009) and Cabral (2009), also creates a barrier to entry and growth for smaller networks. In particular, on-net/off-net price differentials create *tariff-mediated network externalities* (Laffont *et al.* 1998b), which make larger networks more attractive to consumers than smaller networks. When on-net calls are priced below off-net calls, *ceteris paribus,* subscribers to large networks experience lower average call charges since more of their calls are made on-net. This makes larger networks more attractive and places smaller networks at a competitive disadvantage. Call externalities reinforce this effect since, when large networks set high off-net prices, subscribers to smaller networks will receive fewer calls, further reducing their ability to compete.

In addition, as shown in Berger (2005) and Hoernig (2007), in the presence of call externalities large networks charge higher off-net prices, and create

[15] See Section 3.2.

higher on-net/off-net price differentials, than smaller networks. This further impedes the ability of smaller networks to compete by creating "access deficits" which can result in a permanent net outflow of termination payments to larger networks. Differential pricing of off-net calls means that even with a "balanced calling pattern", call traffic between large and small networks will not be in balance.

The regulation of mobile termination rates based on fully allocated costs, or LRIC+, consequently exacerbates the incentives of mobile operators to engage in network-based price discrimination, resulting in static welfare losses and barriers to entry and growth for smaller networks. Indeed, high off-net call charges are a distortion in the structure of prices potentially as serious as the distortion in prices that the regulation of mobile termination charges was designed to repair in the first place (i.e. the subsidy of mobile subscription via high termination charges), and are particularly damaging to long-run entry and competition.

A move to "bill-and-keep" for mobile termination rates — as suggested by Berger (2004) (2005), DeGraba (2003) (2004), Littlechild (2006), Quigley and Vogelsang (2003) and others — would likely result in a more efficient wholesale and retail price structure, help to eliminate barriers to entry caused by "tariff-mediated" network effects, and increase welfare and competition in the mobile market. And as we argue below, these conclusions survive the theoretical objections to reducing MTRs, or adopting bill-and-keep, which have received attention in the recent economic literature, and been much-aired in recent regulatory debates.

The remainder of this paper is organized as follows. Section 2 describes the recent academic literature on call externalities and competition between mobile networks, leading to the main conclusions noted above. Section 3 considers some evidence on the importance of call externalities in both theory and practice. Section 4 presents the simple theoretical arguments in favour of adopting bill-and-keep, and Section 5 discusses arguments against reducing MTRs. Finally, Section 6 addresses the issue of whether bill-and-keep would lead to reception charges for mobile subscribers, and their implications for welfare-optimal termination charges and economic efficiency. Section 7 concludes.

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2 Call Externalities and Network-Based Price Discrimination

This section summarizes the results of a number of papers which analyze the interaction of call externalities with pricing and competition in mobile networks, including Jeon *et al.* (2004), Armstrong and Wright (2009b) and Hoernig (2007). The key conclusions of this analysis are that call externalities create a strategic motive for off-net/on-net price discrimination which can lead to socially inefficient tariff structures, and create an entry barrier for small networks which are unable to profitably replicate incumbents' pricing strategies. Further, high mobile-to-mobile termination rates, coupled with high charges for off-net calls, can be used strategically by incumbent operators to either prevent entry or reduce competition from new entrants into their markets, even in the absence of call externalities, as shown by Calzada and Valletti (2007), Lopez and Rey (2009) and Cabral (2009).

Jeon, Laffont and Tirole (2004) Jeon *et al.* (2004) analyze competition between two symmetric communications networks which compete in nonlinear prices, and in which both senders and receivers of calls benefit from them — i.e. in the presence of call externalities. Specifically, they assume that a sender obtains a gross surplus $u(q)$ from a call of length q, while the receiver obtains a surplus of $\widetilde{u}(q) = \beta u(q)$, where $\beta > 0$ is a measure of the strength of the call externality. Each network i charges its subscribers a fixed fee F_i, and per-unit call charges p_{ii}^* for on-net calls and p_{ij}^* for off-net calls, for $i, j = 1, 2$.

Jeon *et al.* (2004) show that, with "network-based price discrimination" (i.e. when firms set different prices for on-net and off-net calls), each firm fully internalizes the call externalities on its own network, and sets an on-net price equal to marginal cost less a factor which depends upon the size of the call externality. By contrast, because off-net call charges affect the welfare of consumers *on the rival network*, they are subject to strategic manipulation.

Specifically, when c_O is the marginal cost of originating a call and c_T is the marginal cost of terminating a call, the profit-maximizing *on-net price* for network i is equal to the social-welfare-maximizing price,

$$p_{ii}^* = c_O + c_T - \widetilde{u}'\left(q(p_{ii}^*)\right). \tag{1}$$

Since each firm has a monopoly in the market for on-net calls on its own network, it uses the efficient on-net call price p_{ii}^* to maximize the total surplus, and the fixed charge F_i to extract consumer surplus. Hence, both networks

choose the same on-net price regardless of their market shares, and on-net calls are priced below total marginal cost.

Noting that in equilibrium $\widetilde{u}'\left(q(p_{ii}^*)\right) = \beta p_{ii}^*$, equation (1) may be rewritten as

$$p_{ii}^* = \frac{c_O + c_T}{1+\beta}. \tag{2}$$

Thus in the absence of a call externality ($\beta = 0$), on-net prices for each network are set equal to marginal cost, and always exceed zero for any finite value of β.

By contrast, given that network i has market share α_i, the equilibrium profit-maximizing *off-net price* for network i is given by[16]

$$p_{ij}^* = \begin{cases} \frac{(1-\alpha_i)(c_0+a)}{1-\alpha_i(1+\beta)} & \text{for } \alpha_i < \frac{1}{1+\beta}, \\ +\infty & \text{otherwise,} \end{cases} \tag{3}$$

where a is the mobile-to-mobile termination charge, which is assumed to be equal for the two networks. Note that from (3), $\frac{\partial p_{ij}^*}{\partial \alpha_i} > 0$.[17] Hence a larger network charges a higher off-net price, and has a higher off-net/on-net price differential, than a smaller network.

In a symmetric equilibrium, when $\alpha_i = \alpha_j = \frac{1}{2}$, the equilibrium off-net price is given by

$$p_{ij}^* = \begin{cases} \frac{c_0+a}{1-\beta} & \text{for } 0 \leq \beta < 1, \\ +\infty & \text{for } \beta \geq 1, \end{cases} \tag{4}$$

for each network. In the absence of a call externality ($\beta = 0$), the off-net price is equal to $c_O + a$ and the on-net price to $c_O + c_T$: the on-net/off-net price differential is therefore completely determined by $a - c_T$, the difference between marginal termination costs and the termination charge.[18]

When the call externalities is taken into account, however, strategic considerations change this result. Call externality create incentives for each firm to increase its off-net price in order to reduce the number of calls made to

[16] Equation (3) is obtained by maximizing network i's profit with respect to p_{ij} for a given market share, adjusting the fixed charge to keep its market share constant when it changes its off-net price, and then using the fact that $p_{ij}^* = u'\left(q(p_{ij}^*)\right)$ to obtain the equilibrium price.

[17] Specifically, $\frac{\partial p_{ij}^*}{\partial \alpha_i} = \frac{(c_0+a)\beta}{[1-\alpha_i(1+\beta)]^2}$.

[18] De Bijl and Peitz (2002, ch. 6.4) also solve for the equilibrium pricing structure with two-part tariffs and price discrimination in the absence of a call externality. As in Jeon *et al.* (2004), both on-net and off-net prices are set equal to marginal cost, and therefore the on-net/off-net price differential is completely determined by the reciprocal termination charge.

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the rival network, thereby reducing the attractiveness of the rival network to subscribers. Further, when the receiver of a call benefits by as much as, or more than, the sender (i.e. when $\beta \geq 1$), this leads to what Jeon *et al.* (2004) refer to as a "connectivity breakdown," where both networks set off-net call charges so high as to eliminate off-net calling altogether. Intuitively, a network's profitability is determined by the attractiveness of its offer *relative* to that of its competitor. By allowing off-net calls, a network bears the cost of those calls and, if the receivers enjoy a sufficiently high surplus from receiving calls, this makes the other network relatively more attractive.[19]

In less drastic cases, when $\beta < 1$, competition for market share leads to "suboptimal connectivity." That is, off-net prices which result in too few off-net calls being made relative to the welfare optimum. This can be seen from the fact that the social-welfare-maximizing off-net price is equal to the on-net price in equation (1). From (4), two factors potentially increase the firms' off-net prices above the first-best value: the access charge a, and the call externality effect represented by $\frac{1}{1-\beta}$. Comparing equations (2) and (4) it is clear that, even when the reciprocal termination charge a is set equal to marginal cost c_T, equilibrium off-net call charges still exceed the efficient level due to the strategic effect induced by the presence of the call externality.[20]

Armstrong and Wright (2009b) Armstrong and Wright (2009b, Section 3) use a set-up similar to that of Jeon *et al.* (2004), to analyze on-net and off-net pricing and termination charges in an oligopolistic market which includes n mobile firms and a fixed network.[21] In contrast to Jeon *et al.* (2004), however, they assume that the receiver of a mobile-to-mobile call of length q obtains a surplus $b \cdot q$, where $b > 0$ is the measure of the strength of the mobile-to-mobile call externality; and the receiver of a fixed-to-mobile call of length q obtains a surplus $B \cdot q$, where $B > 0$ is the measure of the strength of the fixed-to-mobile call externality. Armstrong and Wright (2009b) therefore restrict the analysis

[19] This result requires that the market is "covered" — i.e. that every consumer subscribes to a network.

[20] This can also be seen by noting that $\frac{\partial p_{ij}^*}{\partial a} = \frac{1}{1-\beta} > 1$ when $\beta > 0$ in (4), so an increase in the reciprocal termination charge results in an increase in both networks' off-net prices *which exceed the increase in the termination charge.*

[21] Their analysis builds on the standard framework of two-way interconnection between symmetric networks of Laffont, Rey, and Tirole (1998b) and Gans and King (2001), extended to take into account fixed-to-mobile calls as described in Armstrong (2002, section 3.1) and Wright (2002a), and the presence of more than two mobile firms. See Armstrong and Wright (2007) for a more detailed description and analysis of an n-firm generalization of the Hotelling duopoly framework.

to linear call externalities.[22]

The welfare-maximizing fixed-to-mobile call price in the set-up of Armstrong and Wright (2009b) is given by

$$P^* = C + c_T - B, \tag{5}$$

where C is the marginal cost of origination on the fixed network. That is, the socially optimal fixed-to-mobile price is equal to the total marginal cost of a fixed-to-mobile call, less the relevant call externality parameter. As in Jeon *at al.* (2004), the profit-maximizing on-net price for network i is equal to the social-welfare-maximizing call price, which is given here by

$$p_{ii}^* = c_O + c_T - b, \tag{6}$$

or the mobile network's on-net marginal cost adjusted *downwards* to reflect the call externality its subscribers enjoy from being called by people on the same network.

By contrast, in a symmetric equilibrium, each mobile firm sets its off-net price equal to

$$p_{ij}^* = c_O + a + \frac{1}{n-1}b, \tag{7}$$

where a is the reciprocal mobile-to-mobile termination charge. This exceeds the welfare-maximizing price given by equation (6), and is equal to a network's marginal cost for an off-net call adjusted *upwards* to reflect the fact that when a network's subscribers make fewer calls to subscribers of other networks, the utility of subscribers to other networks is reduced because of the call externality. As Armstrong and Wright (2009b, p. 94) observe, "*this represents an anti-competitive motive to set high off-net retail call charges.*"

Although the qualitative effect of call externalities on the networks' mobile-to-mobile prices is the same as in Jeon *et al.* (2004), because of the different assumptions on the nature of the call externality the model of Armstrong and Wright (2009b) never leads to infinite off-net mobile-to-mobile prices and "connectivity breakdown."[23] As in Jeon *et al.* (2004), however, setting the

[22] One way of understanding this distinction is to note that Jeon *et al.* (2004) assume that the "total surplus" from a call, $(1+\beta)\, u(q)$, is "shared" by the sender and receiver in proportions $\frac{1}{1+\beta}$ and $\frac{\beta}{1+\beta}$ respectively. Armstrong and Wright (2007), on the other hand, treat the sender's utility as being independent of the benefit obtained by the receiver.

[23] In the Armstrong and Wright framework, as the charge for off-net calls rises, the harm to a mobile firm's own subscribers eventually dominates the harm done to a rival's subscribers, and so there is never any such breakdown. For a large enough externality parameter, b, however, their model can predict negative on-net prices.

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reciprocal mobile-to-mobile termination charge equal to marginal cost, i.e. $a = c_T$, does not lead to efficient off-net prices, and does not eliminate on-net/off-net price differentials.

Both models thus predict that the observed differences in on-net and off-net call charges are not solely due to mobile-to-mobile termination rates which exceed marginal cost. Rather, networks set high off-net prices in order to reduce the number of calls received by subscribers on rival networks, thus reducing the rival networks' ability to compete. Mobile-to-mobile off-net prices are distorted away from their welfare-maximizing levels by both the regulated mobile-to-mobile termination rate a, and by the "strategic effect," which in the model of Armstrong and Wright (2009b) is represented by the term $\frac{1}{n-1}b$ in equation (7).[24]

When the prices of fixed-to-mobile calls are regulated at cost, so that $P = C + A$, where A is the fixed-to-mobile termination charge, from (5) the socially optimal fixed-to-mobile termination charge in Armstrong and Wright's model is given by

$$A^* = c_T - B, \tag{8}$$

i.e. the mobile networks' marginal cost of termination less the fixed-to-mobile call externality parameter. In the absence of regulation, but assuming that fixed networks and mobile networks are not viewed as substitutes for each other by consumers, the optimal fixed-to-mobile access charge is still given by (8). This is because, when fixed and mobile networks are not substitutes, fixed networks have no strategic motive for setting fixed-to-mobile call prices above marginal cost, so long as they are able to extract consumer surplus via fixed fees.[25] Hence, setting the fixed-to-mobile access charge according to (8) is likely to be approximately optimal even in the absence of regulation of fixed-to-mobile retail prices.

The socially optimal mobile-to-mobile termination rate, which sets off-net charges equal to on-net charges (i.e. $p^*_{ij} = p^*_{ii}$), is given by

$$a^* = c_T - \frac{n}{n-1}b. \tag{9}$$

[24] Armstrong and Wright (2009b) note a difficulty in reconciling the observed on-net and off-net price differentials reported in the UK in 2000/01 with the prices predicted by their model. Using more recent data, Armstrong and Wright (2007) find observed price differentials to be more consistent with their framework. It is worth noting that, in both cases, the data they employ includes a mixture of linear and non-linear prices, and monthly subscription fee revenue.

[25] Armstrong and Wright (2009a, Section 3.3) consider some of the implications of fixed-to-mobile substitution.

Hence, for $B \leq (\frac{n}{n-1})b$, the socially optimal fixed-to-mobile termination rate A^* exceeds the welfare-maximizing mobile-to-mobile rate a^*.[26] The socially optimal mobile-to-mobile termination charge is lower than fixed-to-mobile charge to off-set the strategic motive for setting mobile-to-mobile off-net charges which are too high relative to their first best levels, and these strategic motives are essentially absent for fixed networks.

As in Berger (2005) and Gans and King (2001), Armstrong and Wright (2009a) also show that, if mobile networks are able to coordinate on reciprocal termination charges, they will choose a mobile-to-mobile termination rate below marginal cost, and below the socially optimal level given by (9), in order to relax downstream retail competition for subscribers.[27]

Armstrong and Wright (2009b, pp. 94-95), however, also note a possible anti-competitive motive for incumbent mobile networks to prefer high termination charges when facing the threat of entry by smaller networks, vis. that "*high mobile-to-mobile termination charges may deter entry or induce exit of a smaller rival.*" By setting mobile-to-mobile termination rates above cost, incumbent mobile networks can induce network effects which make entry less attractive for newcomers. In particular, high termination rates result in higher prices for off-net calls, which harms smaller networks since most of their subscribers' calls will be made off-net. Call externalities reinforce this effect: when the incumbent networks set high off-net prices, subscribers of smaller networks will receive relatively fewer calls, thus reducing the utility from joining a smaller network. This is a theme which has been taken up by Hoernig (2007), Calzada and Valletti (2008), Lopez and Rey (2009) and Cabral (2009).

Hoernig (2007) The argument that high off-net prices can be used to create network effects which reduce the competitive threat posed by smaller networks is developed in Hoernig (2007), who analyzes the duopoly model of Jeon *et al.* (2004) with two asymmetrically-sized networks. He assumes that the termination charge is set by the regulator, and analyzes Nash equilibria with price discrimination between on-net and off-net calls, for both linear and two-part tariffs. He also considers the possibility that the larger network engages in a form of "predatory pricing," whereby it leverages the tariff-mediated network externality to reduce the profits of the smaller network.

Hoernig (2007) finds that call externalities and asymmetries in network size

[26] It is not easy to think of a good reason for the call externality parameters to be different for the two types of call. Hence, $B = b$ appears to be a reasonable assumption.

[27] See the discussion in Section 5.1 below.

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have strong effects on the equilibrium on-net and off-net prices, and the resulting price differentials. Specifically, the large network charges higher off-net prices, and creates a higher on-net/off-net differential, than the smaller network, in order to improve its relative competitive position by making the rival network less attractive. This result can be readily obtained from equations (2) and (3) above.[28]

As a result, even with a "balanced calling pattern" (i.e. when each consumer calls every other consumer with the same probability in the absence of any tariff differentials), the traffic between the two networks will not be in balance, because the number or the duration of calls is affected by the different prices charged by the two networks. Therefore, when the reciprocal access charge is above marginal cost, the smaller network incurs a permanent access (i.e. interconnection payment) deficit due to its lower off-net price. Hoernig (2007) shows that this result holds under both linear and two-part tariffs. With linear tariffs the larger network also charges a higher on-net price, while with two-part tariffs both firms set the on-net price at the socially efficient (and profit-maximizing) level.

Hoernig (2007, Section 5) argues that a large network is capable of further harming the small network by adopting an anti-competitive, predatory-pricing strategy aimed at inducing the smaller network to exit the market. By choosing a larger on-net/off-net price differential, the large network can further reduce the smaller network's access revenue (if access is priced above cost), and the call externality enjoyed by its customers. This reduces the smaller network's profit.[29]

As Hoernig (2007) stresses, call externalities are crucial for his results. In the absence of call externalities, equilibrium on-net/off-net price differentials are determined solely by the reciprocal access charge. In the presence of the

[28] One way of explaining this is that with call externalities, an increase in a network's off-net price has a first-order effect on the attractiveness of the rival network for subscribers. This effect is greater for larger networks, because larger networks have more subscribers who call the subscribers of the other network and generate a call externality for them. In other words, with call externalities, receiving calls from the other network is relatively more important for the smaller network's subscribers.

[29] This "predatory pricing" strategy depends on the large firm being able to "commit" itself to maintaining high off-net charges, even though they are not profit-maximizing if the smaller firm remains in the market. (See our discussion of a related commitment issue in the subsection immediately below). Various means of making such strategies "credible" have received attention in the literature, e.g. reputation effects in the presence of incomplete or asymmetric information, and financing constraints. Motta (2004, Ch. 7) contains a recent exposition.

call externalities, this differential is also driven by differences in market shares between networks and by strategic motivations.

Calzada and Valletti (2008) While Hoernig (2007) assumes that termination charges are set by the regulator, other papers consider networks' incentive to strategically coordinate on reciprocal access charges. Gans and King (2001) (building on Laffont *et al.*, 1998b) showed that, with network-based price discrimination, networks would like to agree on a reciprocal access charge below marginal cost in order to relax downstream price competition, and increase profits. The intuition is that below-cost access charges make off-net calls cheaper than on-net calls, hence consumers favour smaller networks and networks bid less aggressively for market share. (See Section 5.1 below).

Building on this intuition, Calzada and Valletti (2008) argue that incumbent mobile networks may wish to set reciprocal termination charges above the profit-maximizing level, in order to deter the entry of potential rivals. They consider an oligopoly model with network-based price discrimination in which the incumbent firms negotiate termination rates which apply to all firms, including new entrants. Since the firms' profits are not neutral with respect to the termination charge, the incumbent operators recognize that the level of the access charge affects *ex post* profitability, and thus the attractiveness of entry *ex ante*. Given a fixed cost of entry, Calzada and Valletti (2008) identify circumstances in which incumbents want to set an inefficiently high access charge which deters the entry of potential rivals into the industry. Whenever incumbents do so, they create an allocative distortion as off-net prices then exceed marginal cost. This behavior also limits the gains from entry for consumers (Calzada and Valletti, 2008, p. 1243).

Call externalities — which Calzada and Valletti model by assuming that groups of people that tend to call each other more often join the same network — further increase incumbents' incentives to coordinate on a high access charge in order to deter entry. The reason is that a high access charge makes it less attractive for an incumbent network's subscribers to join an entrant network, because doing so means that a larger fraction of their calls will be made off-net. Call externalities of this type imply that the entrant suffers more from any mark-up of the access price, while the incumbents suffer less.

The use of high MTRs to deter entry in the Calzada and Valletti model requires that incumbent mobile operators are able to commit to maintaining these charges *ex post*, even if entry does occur. As noted above, such commitment assumptions have been criticized. In the absence of the ability to

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commit to high MTRs post-entry, entry deterrence will not be possible.[30] This argument is recognized by Calzada and Valletti who point to the example of Turkey where precisely the scenario they envisaged may have occurred.[31] They also argue that in practice interconnection deals are changed very rarely, and that, "*commitment can be sustained through regulatory environments where telecommunications operators typically offer binding access undertakings and so cannot easily change them ex post.*"[32] Thus the ability of mobile firms to commit to high charges may depend upon the economic and legal framework in which MTRs are determined, an issue the majority of the literature does not discuss.[33] For the purposes of this paper, however, the commitment issue is of less significance since we are solely concerned with the effects that *regulated* MTRs have on entry and growth by smaller networks, and not with mobile networks' ability to agree on the levels of MTRs in the absence of regulation.

Lopez and Rey (2009) Calzada and Valletti (2008) study how incumbent mobile firms can reduce rivals' profitability in order to limit entry, at the expense of a loss in their own profit. Lopez and Rey (2009), by contrast, show how an incumbent *monopolist* can increase the reciprocal termination charge to increase its own profits at the expense of a smaller rival or new entrant, when subscribers incur switching costs to move from one network to the other. If all customers initially subscribe to the incumbent network, charging a high enough reciprocal termination charge creates price-mediated network effects that allow the incumbent to keep the entrant out of the market entirely.

[30] Mason (2009) criticizes this aspect of Calzada and Valetti's analysis. Mason also argues that the incumbent mobile firms in their model could equally well deter entry by lowering the reciprocal termination charge below the profit-maximizing level. Calzada and Valletti (2008, p.1238) consider this possibility and reject it because "*negative mark-ups can easily imply negative access charges which are difficult to enforce.*" That is, prices may be bounded below by "bill-and-keep" (i.e. zero access charges). Lopez and Rey (2009) make a similar point.

[31] Calzada and Valletti (2008, pp. 1224-1225). See also Atiyas and Dogan (2007).

[32] Calzada and Valletti (2008, p. 1235).

[33] Two exceptions are Binmore and Harbord (2005) and Armstrong and Wright (2007). Binmore and Harbord (2005) assume that MTRs are determined in negotiations between mobile and fixed networks which take place 'in the shadow of the regulator.' Armstrong and Wright (2007, Section 3.5) consider a 'winner-takes-all' bargaining model in which the fixed-to-mobile termination charge depends upon the relative bargaining power of the fixed versus mobile networks, and results in mobile firms offering to interconnect at a price less than marginal cost ($c_T - B$ in their notation). Calzada and Valletti (2008, p. 1235) suggest that their negotiation set-up can be re-interpreted as a set of bilateral negotiations between identical firms under a non-discrimination requirement.

Lopez and Rey (2009) note that, as in Gans and King (2001), increasing the reciprocal termination rate above cost reduces both operators' profits if the market is shared. Hence entry-deterring strategies are profitable only when they result in complete market foreclosure. Finally, the network effects created by on-net/off-net price discrimination are a key ingredient for profitable foreclosure in this analysis. In the absence of network-based price discrimination, the incumbent cannot profitably manipulate the access charge so as to foreclose competition.[34]

Cabral (2009) Nearly all of the models considered in the literature are essentially static in nature. An exception is Cabral (2009) who models the dynamics of price competition in the presence of network effects.[35] Cabral (2009) considers a dynamic model of competition between two networks, in which network size evolves over time because consumers die with a constant hazard rate and are replaced by new consumers.[36] Firms compete for new consumers by offering subscription prices, which may be below cost. Each consumer has a privately known preference for the networks and, after joining one network, stays with it until death. Network effects arise because, in each period, a consumer enjoys a benefit which is increasing in the size of the network he has joined.

In this general framework, Cabral studies network pricing decisions and the stationary distribution of market shares. The equilibrium state is generally asymmetric, since a larger network is always more likely to attract new subscribers than a smaller network. Indeed, for sufficiently strong network effects, the market is characterized by "increasing dominance" (i.e. the larger network increases in size relative to the smaller network), and differences in pricing are thus exclusively driven by "market power considerations" related to capturing new subscribers. Since consumers are willing to pay more to join a larger network, in equilibrium larger firms charge higher subscription prices, i.e. spend less on subsidizing subscription. Cabral (2009) uses his model to estimate long-run market share asymmetries.[37]

[34] Although Lopez and Rey (2009) do not consider call externalities, including them in their analysis would exacerbate network effects and thus make the incumbent monopolist's foreclosure strategy even more effective.

[35] See also Hoernig (2009a) for a complementary analysis.

[36] A disadvantage of considering a complex dynamic model is that there is no closed-form analytical solution. Even for very simple functional forms, Cabral needs to resort to numerical simulations.

[37] In one of his simulations, Cabral shows that long-run market shares will converge to

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Cabral (2009, Section 5) applies this framework to the analysis of termination charges in mobile markets. In this case, network effects arise because operators set different on-net and off-net prices, so that the utility from being connected to a given network is increasing in the number of users on the network (tariff-mediated network externalities). He shows that, if termination charges include a positive markup over marginal cost, then the degree of market dominance increases, and larger networks tend to become even larger. In addition, high access charges increase barriers to entry. Specifically, markups in access charges decrease the value of an entrant, regardless of whether termination charges are symmetric or asymmetric.

3 Internalizing Call Externalities and Network Effects

The preceding section summarized the results of a number of papers which analyze the interaction of call externalities with pricing and competition in mobile networks, and the likelihood that above-cost MTRs can be used strategically to either prevent entry or reduce competition from new entrants in mobile markets.

Despite the prominence of call externalities in the recent theoretical literature, however, they have until recently effectively been ignored in European regulatory debates and decisions.[38] So it is worthwhile asking whether receiver benefits or call externalities are important in practice, and not merely of theoretical interest. We address this question here by first considering whether, in principle, the internalization of call externalities potentially reduces the relevance or significance of the recent theory. Second, we present some (albeit indirect) empirical evidence which suggests that call externalities may be playing a significant role in European mobile markets.

3.1 Internalizing Call Externalities

As noted by Armstrong and Wright (2009b, p. 94), the Competition Commission's 2003 'calls to mobiles' inquiry in the UK barely discussed call externalities at all, and this has remained the pattern of subsequent regulatory

80% for the larger (incumbent) network and 20% for the smaller (new entrant) network.

[38] For some recent exceptions see EC (2009b) and ERG (2009).

inquiries.[39] In 2003, Ofcom nevertheless suggested that call externalities did not justify any adjustment to termination charges because

> "*it was possible that call externalities were already largely internalized as people tended to be in stable calling relationships with each other. The caller might be prepared to make a call even if his expected benefit was less than the price, because he expected that a further call (or calls) would be generated, initiated and paid for by the other party, from which he would receive a benefit without having to pay.*"[40,41]

The empirical basis for these assertions is unclear. In any event, the strategic incentive to engage in off-net/on-net price discrimination discussed above depends primarily upon the existence of receiver benefits from receiving calls, which is not in dispute, and less upon the degree to which the associated externalities may be internalized by people in stable calling relationships. Therefore, even if call externalities are partially or fully internalized, to the extent that a call to a subscriber on a rival network benefits the receiver, a network still has a strategic incentive to set inefficiently high off-net prices to reduce the number of calls received by rival networks' subscribers.

This can be seen in the recent analysis of Cambini and Valletti (2008), who consider a model of "call propagation" in which each outgoing off-net call results in a fraction x of incoming calls. Comparing their results with Jeon *et al.* (2004), the authors show that networks will have reduced incentives to use off-net/on-net price discrimination to induce a connectivity breakdown when outgoing and incoming calls are complements, but that off-net/on-net price differentials do not disappear.

[39] There was no mention of call externalities in Ofcom's extensive 2007 review of MTR regulation. As noted in footnote 8 above, the Competition Commission's panel in 2008/09 was prevented by the Competition Appeal Tribunal, with Ofcom's support, from considering any recent economic evidence in favour of adopting bill-and-keep, and this included call externalities.

[40] Competition Commission (2003, paras 8.257 to 8.260). See also Oftel (2003, para D.16).

[41] Ofcom (2009, para A1.28) presents some evidence on sender versus receiver charges in the United States, and infers that since "*in the US the cost of the call is effectively equally shared between caller and receiver*," the most plausible implication is that,"*consumers value incoming calls as much as they value outgoing calls.*" They note in paragraph 1.30 however, that "*whether consumers could take action to internalise this, is a separate question which will have to be addressed separately.*"

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Specifically, Cambini and Valletti (2008) find that the profit-maximizing off-net price is equal to

$$p_{ij}^{*} = \frac{c_0 + a - (a - c_T)x}{1 - \beta(1 - x)}, \tag{10}$$

which takes finite values for $0 \leq \beta \leq \frac{1}{1-x}$. This is lower than the off-net price obtained by Jeon *et al.* (2004) (see equation (4) above), showing that call propagation does reduce a network's incentive to set high off-net prices. Note, however, that even if the termination rate is set equal to marginal cost (i.e. $a = c_T$), the strategic incentive to inefficiently increase the off-net price above marginal costs remains, since equation (10) is higher than $c_O + c_T$ as long as $x < 1$ (which is the empirically relevant case).[42]

Call propagation, in any event, is not identical to the notion of "internalizing call externalities."[43] Suppose instead that individuals in stable calling relationships fully internalize the call externality, as hypothesized by Ofcom's quote above, and consider the model of Jeon *et al.* (2004). Then the sender of a call acts so as to maximize the total utility of the call, which is given by $(1 + \beta)u(q)$, and so sets $p_{ij}^{*} = (1 + \beta)u'\left(q(p_{ij}^{*})\right)$.

It is straightforward to show that, in this case, the equilibrium off-net price for a network i with market share α_i is given by[44]

$$p_{ij}^{*} = \begin{cases} \frac{(1-\alpha_i)(c_0+a)}{1-\alpha_i(1+\frac{\beta}{1+\beta})} & \text{for } \alpha_i < \frac{1}{1+\frac{\beta}{1+\beta}}, \\ +\infty & \text{otherwise,} \end{cases} \tag{11}$$

which is also lower than the off-net price in equation (3) above. Nevertheless, a strategic motive to increase off-net prices above marginal cost remains, since even if $a = c_T$ and $\alpha_i = \frac{1}{2}$ the off-net price in equation (11) is higher than $c_O + c_T$. Moreover, when market shares are asymmetric a "connectivity breakdown"

[42] Cambini and Valletti (2008) cite the empirical evidence in Taylor (2004), who in turn cites the point-to-point demand models of Southwestern Bell and Telecom Canada, which suggest that "*a call in one direction stimulates something like one-half to two-thirds of a call in return.*"

[43] Taylor (2004, Section 3) sharply distinguishes call externalities from what he terms "the dynamics of information exchange."

[44] This can be obtained by setting the first-order derivative of network i's profit with respect to p_{ij} equal to zero (see Jeon *et al.*, 2004, p. 105). Since network j's subscribers also send more calls to network i when externalities are internalized in this way, profits from interconnection also increase whenever $a > c_T$. However, this effect has no influence on the optimal choice of p_{ij} by network i.

can still occur,[45] and a large network still has an incentive to create higher on-net/off-net price differentials than a smaller network. The reason is that, even when call externalities are fully internalized, a large network remains more capable of reducing the utility of a smaller network's subscribers, by reducing the number of calls received by each of those subscribers, than *vice versa*.

An additional effect occurs if individuals in stable calling relationships act so as to minimize the total costs of their communication. Then, *ceteris paribus*, an increase in network i's off-net price results in an increase in incoming off-net calls from network j, which will tend to increase its profits, whenever $a > c_T$, without reducing the utility of network i's subscribers. This creates an additional motive for implementing high off-net prices when call externalities are internalized by subscribers to different networks who act as a team. Hence, the degree to which the internalization of call externalities, or related call propagation effects, reduce networks' strategic incentives to engage in on-net/off-net price discrimination is an empirical question which is at present far from being resolved.

3.2 Evidence on Price Differentials and Network Effects

While it is impossible to directly observe the size of receiver benefits, or 'uninternalized' call externalities, indirect empirical evidence suggests call externalities may play a significant role in many European mobile markets. We present three types of evidence here. First, in the presence of call externalities, mobile firms should set on-net/off-net price differentials which exceed the difference between mobile termination rates and their marginal costs. Second, we should observe large imbalances between on-net and off-net calling patterns on mobile networks. Third, if call externalities matter we should observe interconnection traffic imbalances between large and small networks.

3.2.1 Price differentials and network calling patterns

Large price differentials for on-net and off-net calls have indeed been common in many European mobile markets. UK evidence from to 2002 to 2006 is shown in Table 3.1.[46] The average off-net price charged by mobile networks in 2002

[45] By contrast, with symmetric market shares $p_{ij}^* = (c_0 + a)(1 + \beta)$, which remains finite for all finite values of β.

[46] Source: Ofcom (2007b), Figure 4.40. Armstrong and Wright (2009a, p. F275) and Armstrong and Wright (2009b, p. 78) present similar evidence, and Birke and Swann (2006) provide evidence for the period 1999-2003. As Armstrong and Wright (2009b) point out, it

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was 22.6 ppm versus 5.1 ppm per minute for on-net calls. Although by 2006 this differential had been reduced, it remained significant.

Table 3.1 Average call charges in the UK (ppm)

	2002	2003	2004	2005	2006
On-net calls	5.1	5.1	4.9	4.1	3.5
Off-net calls	22.6	17.2	14.3	11.2	8.9
Price differential	17.5	12.1	9.4	7.1	5.4
Average MTRs	10.7	9.9	7.9	5.9	5.5

Note that average on-net call prices are consistently much lower than the corresponding MTRs, illustrating the oft-observed fact that mobile networks do not treat regulators' estimates of "LRIC+" as costs that need to be recovered from calls made on their own network. In the absence of call externalities, theory predicts that the on-net/off-net price differential will be equal to $a - c_T$, the difference between marginal termination costs and the termination rate. Unless marginal termination costs are literally zero, this was never true in the UK according to Ofcom's data, but the numbers in Table 3.1 nevertheless suggest a decline in receiver benefits, or (uninternalized) call externalities, from 2002 to 2006.[47]

Data on on-net/off-net price differentials are difficult to interpret, however, given the arbitrariness of their calculation.[48] Data on calling patterns in the UK present a much more stable picture (see Table 3.2).[49]

is a complicated and somewhat arbitrary task to give precise estimates for the prices of the various types of calls and messages originating on mobile networks, due to the complexity and range of their tariffs.

[47] Ofcom (2009), Annex 9, presents some more recent anecdotal evidence on on-net/off-net price differentials in the UK. For contract customers, Orange charges 12 ppm for on-net calls and 35 ppm for off-net calls once the allowance is used up, giving an on-net/off-net price differential of 23 ppm. (Where the tariff includes unlimited on-net calls, the effective differential between on-net calls and off-net calls is even greater.) Vodafone also charges on-net/off-net price differentials: 20 ppm to 22 ppm. By contrast, O2, 3 and T-Mobile have zero on-net/off-net price differentials.

[48] Ofcom does not explain the sources of the data in Table 3.1, nor whether the method of calculation has remained constant over time. In any event, we know that the numbers comprise a possibly changing mixture call minutes made under pre-pay (linear) tariffs, and post-pay (non-linear) tariffs.

[49] Derived from Figure 4.71 in Ofcom (2008).

Table 3.2 Shares of types of mobile call, UK (%)

	2003	2004	2005	2006	2007	2008
On-net calls	32.74%	31.78%	29.92%	29.84%	31.98%	34.45%
Off-net calls	17.62%	22.39%	22.41%	25.40%	27.40%	27.12%
Ratio	1.86	1.42	1.33	1.18	1.17	1.27

From 2003 to 2008, on-net calls have consistently accounted for 30% or more of all mobile-originated call minutes, while off-net call volumes have remained consistently well below 30%. As noted by Armstrong and Wright (2009a, p. F275), with equal off-net and on-net charges and four roughly symmetric networks, we would expect off-net traffic to be approximately three times greater than on-net traffic, rather than the much lower volume of off-net traffic observed in the data. High prices for off-net calls relative to on-net calls is likely responsible for much of this imbalance in calling patterns.[50] In this case the data does not indicate a dramatic reduction in network-based price discrimination, and the associated network effects, over time.

Data from other European countries such as Spain, France, Sweden and Holland tell a roughly similar story. In Spain there are five mobile operators, Movistar (with a 45% subscriber market share), Vodafone (30.5%), Orange (20.7%), Yoigo (2%), and Rest (1.8%).[51] Data on Spanish mobile calling patterns from 2004 to 2008 is presented in Table 3.3.[52] With equal off-net and on-net charges, at least half of every operators' traffic should be off-net. Instead, over all firms, twice as many calls are made on-net as compared with off-net.

Table 3.3 Shares of types of mobile call in Spain (%)

	2004	2005	2006	2007	2008
On-net calls	51.18%	54.99%	56.25%	57.31%	55.99%
Off-net calls	26.21%	25.50%	26.10%	25.48%	27.63%
Ratio	1.95	2.16	2.16	2.25	2.03

[50] Armstrong and Wright (2009a) suggest that "closed user groups," i.e. groups of subscribers who predominantly make calls within their own group, and substitution between MTM and FTM calls, may also be partly responsible. Note, however, that the existence of closed user groups may itself be partly, if not largely, explained by on-net/off-net price differentials.

[51] CMT (2008, p. 281).

[52] CMT (2008, p. 277).

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The Spanish regulator, CMT, also publishes data on call prices by category. Table 3.4 presents on-net and off-net call prices and MTRs since 2004 (in euro cents per minute).[53]

Table 3.4 Average call charges in Spain (cpm)

	2004	2005	2006	2007	2008
On-net calls	17.37	14.15	13.38	12.18	11.33
Off-net calls	27.38	26.71	22.78	21.36	19.43
Price differential	10.01	12.56	9.40	9.18	8.10
Average MTRs	15.55	13.62	12.12	10.85	9.39

It is possible that on-net/off-net price differentials in Spain are driven almost entirely by MTRs, especially if marginal termination costs are one euro cent per minute or less. The CMT's price data excludes billed minutes, however, which means that it is likely to significantly underestimate off-net call prices, especially since post-pay tariffs often offer very large, or even unlimited, packages of on-net minutes.

France has three mobile operators, Orange France (with a 46.7% subscriber market share), SFR (35.8%) and Bouygues Telecom (16.9%). Recent data on French calling patterns is presented in Table 3.5.[54] Again, even for the largest operator, Orange France, with equal off-net and on-net charges we would expect more than half of its traffic to be off-net. Instead, almost twice as many calls are made on-net as compared with off-net.

Table 3.5 Shares of types of mobile call in France (%)

	Q4 2007	Q1 2008	Q2 2008	Q3 2008	Q4 2008
On-net calls	53.40%	53.83%	52.74%	51.11%	51.32%
Off-net calls	25.43%	25.27%	26.27%	27.36%	27.73%
Ratio	2.1	2.13	2.01	1.87	1.85

Finally, Sweden has four mobile operators, Telesonera (with a 42% subscriber market share), Tele 2 (31.2%), Telenor (17.2%), and H3G (7.9%). Data on Swedish calling patterns is presented in Table 3.6.[55] Again, even for the largest operator, Telesonera, with equal off-net and on-net charges we would

[53] CMT (2008, p. 279, 284). Approximately 20% of these calls are made under pre-pay (i.e. linear) tariffs (p. 280).

[54] Arcep (2009, p. 25).

[55] PTS (2009, Table 20).

expect more than half of its traffic to be off-net. Instead, consistently twice as many calls are made on-net as compared with off-net.

Table 3.6 Shares of types of mobile call in Sweden (%)

	2004	2005	2006	2007	2008
On-net calls	38.52%	47.75%	48.89%	49.02%	48.48%
Off-net calls	21.66%	20.14%	23.30%	24.59%	24.90%
Ratio	1.78	2.37	2.1	1.99	1.95

While data on on-net/off-net price differentials is perhaps too arbitrary to allow us to draw any clear conclusions, data on on-net/off-net calling patterns certainly points to the existence of strong network effects in European mobile markets. The degree to which receiver benefits, or call externalities, play a role in this is not easy to estimate, however.[56]

3.2.2 Traffic imbalances between large and small networks

Hoernig (2007) shows that when large mobile operators charge higher off-net prices than smaller operators, as predicted by the Jeon *et al.* model, interconnection traffic between networks will not be in balance, and smaller networks will face permanent "access deficits", in the sense that their termination outpayments to the larger networks will exceed their inpayments. In the absence of call externalities, however, small and large networks set equal on-net and off-net prices, and their interconnection traffic is balanced. Hence Hoernig (2007) predicts that we should observe traffic imbalances between small and large networks *if and only if* call externalities influence network's off-net pricing decisions.

Small mobile networks in Europe have complained about their traffic imbalances with, and net termination outpayments to, incumbent networks since at least 2005, and the issue was eventually recognized as important by European regulatory authorities by 2008. The European Regulators Group (ERG, 2008, pp. 98-101), for example, considered whether traffic imbalances between networks justified allowing smaller networks higher regulated MTRs. It concluded tentatively in favour of such an approach, so long as small networks faced significant traffic and termination payment imbalances as a result of the

[56] Birke and Swann (2005)(2007) studied network effects in mobile markets using a variety of data and techniques. See Harbord and Pagnozzi (2008) for a more detailed discussion.

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larger networks' on-net/off-net price differentials; and regulated MTRs were significantly above incremental costs.

The ERG observed that the French regulator Arcep had already adopted such a policy in favour of the smaller French network (Bouygues Telecom), and the Portuguese regulator, Anacom, adopted a similar policy towards the third Portuguese operator, Optimus.[57] The Belgian regulator, BIPT, has likewise allowed the new entrant operator BASE a higher regulated MTR, explaining that "*the asymmetry results particularly from the imbalance of incoming traffic between the three operators.*"[58] Finally, H3G UK recently provided the Competition Commission with data on small-network traffic imbalances in eight European countries: Austria, Sweden, Germany, Turkey, UK, Italy, Poland and France (Competition Commission, 2009, p. 205 and p. 215).[59]

While there is little detailed data available on smaller network traffic imbalances, the issue has certainly received a great deal of attention in Europe, and has become a focus of regulatory deliberations. Such traffic imbalances provide some evidence of the importance of call externalities in influencing mobile networks' off-net prices. In theory at least, traffic between small and large networks should be in balance in the absence of call externalities.

4 "Bill-and-Keep" as the Efficient Charging Regime

The early literature on mobile network competition (Laffont *et al.* 1998a; Armstrong 1998; Carter and Wright 1999) showed that firms can use above-cost access charges as a mechanism to obtain higher profits when they compete in linear retail prices. By coordinating on high enough access charges, monopoly call prices can be achieved, and if inter-network traffic flows are symmetric, firms do not bear any burden from the high charges they pay to each other.[60]

[57] The issue has also been recognized by the European Commission as a factor influencing its recent recommendation on MTRs in EC (2009b, p. 16). See also Peitz (2008).

[58] See EC (2006).

[59] See Competition Commission (2009) paragraphs 5.3.1, 5.4.38-5.4.50, and Sections 5.5 and 5.6 for extensive discussions of H3G UK's traffic imbalances. The Commission was prevented by the Competition Appeal Tribunal's "admissibility" ruling from considering the extent to which on-net/off-net pricing differentials and above-cost MTRs contributed to H3G's traffic imbalances (paragraphs 5.4.38 and 5.4.40).

[60] This collusion result is not robust under more sophisticated pricing strategies, however. Armstrong (1988) and Laffont et al. (1998a) demonstrated that, with two-part retail prices, the access charge has a neutral effect on profits: any possible access profit would simply be

On the basis of these conclusions, Carter and Wright (1999, p. 24) argued that bill-and-keep may be the second-best regulatory policy when the first-best (i.e. marginal cost pricing) is unobtainable.

Subsequent papers have extended the analysis in several directions and have shown that networks may wish to agree on interconnect prices *below* marginal cost if networks compete in two-part tariffs with discriminatory prices (Gans and King, 2001), or demand for subscription is elastic (Dessein, 2003). Gans and King (2001) showed that when the operators can discriminate between on-net and off-net calls, below-cost termination rates can soften downstream price competition, allowing firms to obtain higher profits. Hence bill-and-keep arrangements may be undesirable from the consumer's perspective.[61] An opposing position was taken by Cambini and Valletti (2005), who argued that networks may wish to agree on interconnect prices *above* marginal cost if ex-ante investments have to be made, in order to weaken competition over investments. Cambini and Valletti (2003) showed that bill-and-keep may be beneficial due to a positive impact on investments in quality prior to price competition occurring.

All of these papers shared the assumption that only the caller benefits from a call, i.e. no call externalities. As discussed above, however, call externalities have significant consequences for the analysis of competition, equilibrium retail pricing, and optimal regulatory policy. As Hermalin and Katz (2009, pp. 1-3) have recently observed, '*recognition that both sender and receiver enjoy benefits has important implications for efficient pricing to end users and for the efficient pricing of interconnection.*' In the presence of receiver benefits, '*there are theoretical arguments for both positive and negative* access charges.' Indeed, once it is recognized that both parties to a call receive benefits from it, it is surprisingly easy to demonstrate that this fundamentally changes the analysis of welfare-optimal prices and termination rates, and that bill-and-keep is likely to be the efficient charging regime.

passed on to customers via a reduction in their subscription fee, i.e. via the waterbed effect.

[61] See also the discussion in Armstrong and Wright (2009a), and in Section 5.1 below. Gans and King (2001) showed that when firms compete in two-part tariffs and discriminatory prices (but without allowing for call externalities), both on-net and off-net prices will be set equal to perceived marginal costs, with the latter depending upon MTRs. When MTRs are set cooperatively (Gans and King, 2001, Proposition 2), the negotiated MTR is less than marginal cost, so each network makes a loss on interconnection. This is profitable because it makes attracting additional subscribers less valuable, and so price competition is muted. The profit-maximizing symmetric termination charge may be greater or less than zero. In the latter case, bill-and-keep may be as close as firms can get to collusive profit maximization.

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DeGraba (2003) In a very simple and general framework, DeGraba (2003) shows that in the presence of call externalities, access prices equal to a network's cost of completing a call is typically inefficient. He considers a model in which the sender of a call obtains a fraction λ of the total utility of the call, while the receiver obtains a fraction $(1-\lambda)$ of the total utility. The total per-minute cost of a call is $c = c_O + c_T$, where, as above, c_O is the cost of originating a call, and c_T is the cost of terminating a call.

DeGraba (2003) argues that a call can be viewed as a public good jointly consumed by the sender and the receiver, and hence applies the same logic as in a "Lindahl equilibrium." Letting p_s be the price charged to the sender and p_r the price charged to the receiver, the only prices which result in efficient consumption *and* add up to c are

$$p_s = \lambda c \quad \text{and} \quad p_r = (1-\lambda)c. \tag{12}$$

So only in the case $\lambda = 1$ — i.e. in the absence of call externalities — should the sender pay for the entire cost of the call.[62]

If regulation or competition forces networks to set call prices equal to marginal cost, then the optimal access charge that the network of the sender of a call should pay to the network of the receiver is equal to

$$a^* = (\lambda - 1)c_O + \lambda c_{T.} \tag{13}$$

The effective cost of a call to the sender's network is then $c_O + a^* = \lambda c$, and the effective cost to the receiver's network is $c_T - a^* = (1-\lambda)c$. Hence the optimal access charge is such that each network pays a fraction of the cost of producing a call equal to the fraction of the value of the call received by its subscribers. Only when $\lambda = 1$ is the optimal access charge equal to the marginal cost of termination, and it is equal to zero, or even negative if, for example, $\lambda \leq \frac{1}{2}$ and $c_O \geq c_T$.

On the basis of these results, DeGraba (2003) argues that bill-and-keep, by imposing some of the cost of a call on each network, is more efficient than cost-based termination charges. DeGraba (2003) also notes that, since the optimal access charge does not depend on the number of calls originating on one network as opposed to the other, bill-and-keep is more efficient than cost-based termination charges *even when traffic between networks is not in*

[62] Efficient consumption will also be achieved if the sender pays λc and the receiver pays 0 (or indeed any price lower than $(1-\lambda)c$), so it is not necessary to introduce charges for receiving calls to induce consumption efficiency. If $p_r = 0$, the "unrecovered" costs $(1-\lambda)c$ can be recovered via a fixed fee or subscription charges, levied on either party.

balance, contradicting the widely-held belief that bill-and-keep arrangements are only appropriate when traffic between networks is balanced. Another obvious advantage of bill-and-keep is that it is much simpler to implement for the regulator than cost-based termination charges.[63]

Berger (2004, 2005) DeGraba's simple model is not well-suited to analyzing competition between networks. By contrast, Berger (2004) analyzes network competition in linear prices using the standard Hotelling model of Laffont et al. (1998b) in the presence of call externalities. As in the models discussed in Section 2 above, he shows that call externalities have a significant effect on competition because, given the access charge, networks set higher off-net prices to make subscription to the rival network less attractive. Therefore, on-net prices are lower than off-net prices and, contrary to the result of Gans and King (2001), cooperatively agreed access charges may exceed the welfare-optimal charge, even if the cooperatively agreed charge is below marginal cost.

Building on the model of Jeon et al. (2004), Berger (2005) completes the analysis by considering optimal access charges in the presence of nonlinear (i.e. two-part) tariffs and call externalities. He shows that the welfare maximizing termination rate is always less than marginal cost, and quite possibly less than zero.

This result can be obtained by noting that the efficient off-net price is equal to the equilibrium on-net price and, from equation (4), the welfare-maximizing access charge is equal to

$$a^* = \frac{(1-\beta)\, c_T - 2\beta c_O}{(1+\beta)}. \tag{14}$$

Thus the welfare-maximizing access charge is always less than the marginal cost of terminating a call c_T, and for realistic values of β frequently negative (e.g. for $c_O = c_T$ and $\beta > 1/3$). Therefore, in contrast to Gans and King's result, Berger (2005) argues in favor of bill-and-keep, showing that such an arrangement is welfare improving compared to cost-based access pricing.

Similar to Berger's results, Armstrong and Wright (2007) (2009b) show that with two-part tariffs and network-based price discrimination, cost-based

[63] Wright (2002b) criticizes this conclusion, arguing that bill-and-keep does not solve "*the fundamental problem of pricing out network externalities.*" DeGraba (2002) points out that a positive termination charge will typically harm the subscribers of the (e.g. fixed) network, and may consequently reduce the number of subscribers on that network. Hence the net effect on welfare of positive termination charges is at best ambiguous. We discuss these issues further in Section 5 below.

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access pricing can never be optimal from the social viewpoint, when call externalities are taken into account. In realistic cases (see equation (9) above), the optimal access charge can be less than zero. It follows that, from the social viewpoint, bill-and-keep — i.e. $a = 0$ — is an improvement over cost-based access pricing.

5 Arguments Against Bill-and-Keep

The arguments in favour of bill-and-keep in DeGraba (2003), Berger (2004)(2005) and others are not based on an assertion that zero termination charges are necessarily *exactly* welfare optimal. Rather, they rest on the observation that MTRs less than marginal cost, and possibly less than zero, typically are welfare optimal. Hence adopting bill-and-keep is likely to strike the right balance, given that imposing negative termination charges is probably not possible (Gans and King, 2001; Lopez and Rey, 2009).[64] In addition, bill-and-keep has other practical advantages, such as being much simpler to implement than cost-based termination charges.

A number of theoretical arguments *against* reducing MTRs below marginal cost, or to zero, have received attention in the recent literature, however. These arguments focus on the possibly negative consequences of reducing MTRs for subscribers on mobile networks, considered in isolation, and for mobile subscription, or penetration, rates when network externalities matter (e.g. Wright, 2002b). Since these arguments have been most recently, and fully, developed in Armstrong and Wright (2009a), our discussion in this section will focus heavily on their paper.[65]

5.1 Waterbeds and Relaxing Competition for Market Share

The first argument against reducing MTRs below marginal cost, even when it is socially optimal to do so, is that subscribers on mobile networks can benefit from both high fixed-to-mobile and high mobile-to-mobile termination charges.

[64] DeGraba (2003, pp. 209-210) remarks that, "*I concentrate on bill and keep, not because a zero intercarrier compensation rate is likely to give rise to theoretically optimal usage levels, but because the optimal rate may be very close to zero.*" Valletti and Cambini (2005, Section 5) similarly propose bill-and-keep as a practical solution when termination rates less than zero are theoretically optimal.

[65] See also Hoernig (2008).

That mobile subscribers can benefit from above-cost fixed-to-mobile charges follows directly from the "waterbed" effect. An increase in the fixed-to-mobile termination charge above cost increases the flow of termination profits to mobile networks, some or all of which is passed on to mobile subscribers via the waterbed effect. Hence mobile subscribers should prefer fixed-to-mobile termination rates set at the monopoly (i.e. profit-maximizing) level. As Armstrong and Wright (2009a, p. F286) put it, "*high FTM termination charges are a means of transferring surplus from fixed callers to mobile recipients.*"

Since strong waterbed effects mean that most profits from fixed-to-mobile termination charges are passed on to mobile subscribers in the form of lower subscription charges, high fixed-to-mobile termination rates do not necessarily lead to mobile networks earning excessive profits. Mobile firms have consequently argued that whatever consumers in aggregate lose from high termination charges, is regained in lower subscription fees, and hence that fixed-to-mobile termination rates should remain unregulated.[66]

Mobile subscribers can also benefit from above-cost mobile-to-mobile termination rates, since high MTRs make off-net calls more expensive than on-net calls, creating network effects which favour larger networks. This intensifies competition between networks to attract subscribers by reducing their equilibrium fixed fees. The much-cited result is that equilibrium consumer surplus on mobile networks is increasing in the level of the mobile-to-mobile termination rate (Gans and King, 2001; Armstrong and Wright, 2009a). Citing Armstrong and Wright (2009a, p. F286) again,

> "*When the MTM termination charge is raised, this imposes a direct cost on subscribers since they must pay more for off-net calls but this is outweighed by the lower rental charge they pay.* [...] *A high MTM termination charge acts principally as a means by which to transfer surplus from mobile networks to their subscribers.*"

This result has led a number of authors to suggest that mobile networks should prefer to agree on below-cost mobile-to-mobile termination charges, and that such an agreement would harm mobile subscribers who prefer the intense competition created by higher MTRs.[67]

[66] Armstrong and Wright (2009a, p. F284); Competition Commission (2003, paras. 2.390–2.400).

[67] See Gans and King (2001), Armstrong and Wright (2009a). The Royal Economic Society's media briefing "European Decision on Mobile Charges May Not Benefit Customers," emphasizes this aspect of the Armstrong and Wright (2009a) analysis, suggesting that, "*re-*

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While these arguments have been much aired in recent regulatory debates, they are subject to a number of important caveats. The argument with respect to fixed-to-mobile termination rates is incomplete in two important respects. First, as observed by Armstrong and Wright (2009a, p. F284), even if all fixed-line subscribers have a mobile phone, high termination rates still create an allocative inefficiency, and hence the gain to mobile subscribers from low subscription charges is always outweighed by the welfare loss on the fixed network from high fixed-to-mobile termination rates.

Second, the argument loses much of its force when call externalities, or receiver benefits, matter. To see this note that, with call externalities, the total surplus created on a mobile network by fixed-to-mobile calls can be written as

$$S_F = (a_F - c_T)q_F + \widetilde{u}\,(q_F)\,, \tag{15}$$

where a_F is the fixed-to-mobile termination rates and q_F the quantity of fixed-to-mobile calls.[68] Now, an increase in a_F above marginal cost increases the profits of mobile network, some or all of which is passed on to mobile subscribers via the waterbed effect, but simultaneously reduces the utility received by the mobile network's subscribers from fixed-to-mobile calls. As observed by Armstrong and Wright (2009b, p. 93), this means that a mobile network no longer wishes to maximize fixed-to-mobile profits, given by $(a_F - c_T)q_F$, but total fixed-to-mobile surplus S_F. The fixed-to-mobile termination rate which maximizes S_F can be above or below marginal cost, c_T, and even below zero. Hence a fixed-to-mobile termination rates below c_T may not only be socially optimal, as noted in Section 2 above (see equation (10)), but also optimal for the mobile network's subscribers. Thus, we can no longer say that setting a fixed-to-mobile termination rate above marginal cost, or even above zero, benefits mobile subscribers considered in isolation.

A third caveat is of course that the argument for high fixed-to-mobile termination rates depends upon the strength of the waterbed effect, about which we can say little in practice. Some preliminary results can be found in Genakos and Valletti (2007).

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ducing termination charges to very low levels — such as those in the EU's guidance — may come at a cost to mobile subscribers since ultimately mobile operators may end up competing less aggressively for their customers."

[68] Recall that $\widetilde{u}\,(q) = \beta u\,(q)$ in the Jeon *et al.* formulation. In Armstrong and Wright's (2009b) notation this becomes, $S_F = (a_F - c_T + B)q_F$. Hence, the call externality B has exactly the same effect on a network's choice of the fixed-to-mobile termination charge as a reduction in its marginal termination cost c_T by B. See Armstrong and Wright (2007, p. 17).

The argument that above-cost mobile-to-mobile termination rates benefit mobile consumers is also incomplete in a number of respects. First, as recently demonstrated by Hoernig (2009b) (see also Harbord and Hoernig, 2009), it is only necessarily true in a duopoly model with two mobile networks.[69] In these models with $n > 2$ firms, although a reduction in the mobile-to-mobile termination rate still mitigates network effects, and hence relaxes competition between mobile networks for market share, the reduction in competition may or may not be sufficient to reduce consumer surplus in equilibrium, and it is less likely to do so the more significant are call externalities, and the larger the number of competing networks.[70]

The upshot is that it is an empirical question whether a reduction in fixed-to-mobile and mobile-to-mobile termination charges will result in an increase or a decrease in welfare and consumer surplus on mobile networks *considered in isolation*, especially in markets with more than two firms. Harbord and Hoernig (2009) recently have addressed this question by calibrating the model in Hoernig (2009b) with data pertaining to the UK mobile market. They estimate the impact on total welfare, consumer surplus and profits of a decrease in MTRs in the UK mobile market from their regulated levels to the alternatives currently being considered in Ofcom (2009), assuming uniform fixed-to-mobile and mobile-to-mobile rates.[71]

Their simulations show that although consumer surplus and economic welfare *may* decrease in the mobile market *considered in isolation* when the level of MTRs is reduced, overall welfare, consumer surplus and firms' profits increase in the telecommunications market as a whole.[72] Depending on the strength of the call externality, the model predicts welfare gains of £360m to £2.5bn per annum, with bill-and-keep consistently resulting in the greatest increase

[69] Hoernig (2009b) solves a general model of competition between an arbitrary number of interconnected telecommunications networks with asymmetries in network size and costs. The model includes tariff-mediated network externalities, i.e. price discrimination between on- and off-net calls, and call externalities.

[70] These results are implied by, rather than explicitly stated in, Hoernig (2009b). We are grateful to Steffen Hoernig for discussing these implications with us in private correspondence.

[71] These alternatives are long-run incremental cost (as specified in EC, 2009a); reciprocal rates with fixed networks; and zero MTRs, or "bill-and-keep". Each of these alternatives is also discussed in EC (2009b).

[72] Harbord and Hoernig (2009) find that consumer surplus increases in the mobile market for a call externality parameter (i.e. β in the Jeon *et al.* formulation) exceeding $\frac{3}{4}$, and welfare in the mobile market increases for β exceeding $\frac{1}{2}$. Some earlier simulation results based on older market data and different assumptions were presented in Market Analysis (2009).

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in overall welfare.[73] Inclusion of the fixed-line operator, multiple asymmetric networks, and call externalities is thus indispensable to assessing the welfare effects of reductions in MTRs on mobile and fixed networks.

In addition, as argued in Section 2, high MTRs exacerbate the network effects associated with 'tariff-mediated network externalities', by increasing mobile on-net/off-net price differentials, and this is to the detriment of smaller networks and new entrants. A reduction of MTRs to zero effectively eliminates the competitive advantage of larger networks, and this should promote growth by smaller networks.[74] A move to bill-and-keep should therefore result not only in a more efficient wholesale and retail price structure in the short run, but also help to eliminate barriers to entry, and thus increase competition and longer-run economic welfare.

5.2 Market Expansion and Network Externalities

Mobile operators in Europe have long argued that higher termination charges result in mobile firms subsidizing connection and acquisition costs for new subscribers, via the waterbed effect, and that this leads to market expansion which benefits new and existing mobile subscribers. In the presence of such network externalities, socially-optimal MTRs should therefore exceed marginal costs. Mobile firms in the UK have been successful in making this argument, and since the Competition Commission's 2003 inquiry have received a "network externality surcharge" on top of their regulated MTRs for this purpose.[75] As Ofcom (2007, p. 147) put the argument:

> "*In the presence of a network externality, not enough consumers may choose to become mobile subscribers from the perspective of society as a whole. This is because some consumers' [...] private benefits do not cover the cost of becoming a subscriber, even though social welfare would be enhanced if they did. [...] To the extent that the subsidy to those marginal subscribers is provided by MNOs, it*

[73] This is in contrast to Commission's own estimate of the benefits of following its *Recommendation* (in EC, 2009c), which predicts welfare gains for the entire European Union for the period 2007-2012 of at most 1 billion euros.

[74] Indeed, when call externalities are absent or small, adopting bill-and-keep can result in negative network effects, and subscribers will, all else equal, prefer to join a smaller network (see Armstrong Wright 2009a, p. F286).

[75] See Competition Commission (2003, pp. 225-252). In 2003/04 an externality surcharge of 0.45 ppm was added to regulated MTRs, and this was subsequently reduced to 0.3 ppm by 2007/08.

is efficient to fund it by raising the prices of all mobile communications services."

Network externality surcharges have also been applied in Belgium, Greece, Italy and Sweden (Cullen International, 2008), although the European Commission (in EC, 2009b) now recommends against this policy.[76]

Despite the reversal by European regulatory authorities on this issue since 2008, Armstrong and Wright (2009a) have recently provided some theoretical support for the policy. Noting that mobile subscribers' utility increases with both the fixed-to-mobile and mobile-to-mobile termination charges in their model, they suggest that '*this observation implies that firms and the regulator can use relatively high termination charges as a means to expand the number of mobile subscribers.*' To demonstrate this formally, they consider a "Hotelling model with hinterlands" in which the total number of mobile subscribers is increasing in the utility they derive from joining one or other of the two networks. The possibility of market expansion introduces "market-level" network effects: when a new subscriber joins a network, the utility of the existing subscribers to any network increases since there are now more subscribers they can call, either on-net or off-net.

A high fixed-to-mobile termination charge results in a larger number of subscribers, since profits from termination are (at least partially) passed on to mobile subscribers via the waterbed effect. The efficient fixed-to-mobile termination rate is therefore above cost. The efficient mobile-to-mobile termination charge is also above cost, because mobile subscribers' surplus is increased by a high mobile-to-mobile termination charge (via the 'softening of competition effect'), thus increasing the number of mobile subscribers. Therefore, Armstrong and Wright (2009a) conclude that the socially efficient MTRs should exceed the marginal cost of termination, and that the fixed-to-mobile and mobile-to-mobile rates should be set at different levels, if feasible.[77]

As discussed in the previous section, these conclusions do not necessarily survive the inclusion of call externalities in the analysis, nor an increase in the number of competing mobile networks. When call externalities matter, a high fixed-to-mobile termination rate does not necessarily increase the surplus of mobile subscribers, since the fixed-to-mobile termination rate which

[76] In its 2008/09 inquiry, the Competition Commission also revisited the issue, and decided that a network externality surcharge was no longer justified, if it ever had been. See Competition Commission (2009, Section 4).

[77] Armstrong (2002), Wright (2002a) and Valletti and Houpis (2005) also found that the welfare-maximizing fixed-to-mobile termination charge is above cost when there is scope for market expansion. These models did not allow for mobile-to-mobile calls, however.

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maximizes S_F in Section 5.1 can be above or below marginal cost, and even below zero. Hence whether or not the fixed-to-mobile termination charge can be used to increase mobile take-up is an empirical question, which depends upon the strength of call externalities and other market parameters, such as the elasticity of demand for fixed-to-mobile calls. And in mobile markets with more than two firms, mobile subscribers' consumer surplus is not necessarily increasing in the mobile-to-mobile termination rate either (and is less likely to be so when call externalities are significant). It is therefore unclear that setting either fixed-to-mobile or mobile-to-mobile termination rates above cost will result in an increase in the number of mobile subscribers, as in Armstrong and Wright (2009a). In theory at least, it could equally well be that MTRs below marginal cost are required to induce market expansion.[78]

The market expansion argument is further undermined by empirical evidence on mobile subscription, or penetration, rates in bill-and-keep countries versus CPNP countries with higher MTRs. Recent studies undertaken for Ofcom (Ofcom 2009, Annexes 5 and 7) find that once data on mobile take-up rates are corrected for multiple subscriptions, which are more common in CPNP countries, there is little measurable difference in penetration rates between bill-and-keep and CPNP countries (see also Analysys Mason, 2008, pp. 7-10). While mobile usage, or call volumes, tend to be much higher in bill-and-keep countries, mobile take-up levels do not appear to depend strongly on the level of MTRs.[79]

6 Receiving Party Pays

In most "bill-and-keep" (or near bill-and-keep) countries (e.g. Canada, Singapore, Hong Kong, the United States), mobile firms have adopted receiving

[78] Hurkens and Jeon (2009) analyze a model with two mobile firms in which consumers subscribe to the network offering the highest utility, provided this exceeds their outside options. The utility obtained from joining a network depends on the tariffs chosen by the networks, and on the number of subscribers to both networks. Hurkens and Jeon (2009) distinguish two effects of mobile-to-mobile termination charges on market penetration: a reduction in the termination rate relaxes competition, but it also helps to internalize network externalities (when a firm attracts an additional subscriber, it creates positive externalities for the other firm since the latter's consumers can then make off-net calls to the new subscriber). The former reduces mobile penetration, while the latter expands it. The socially optimal termination charge can be above or below marginal cost depending upon which effect dominates, which in turn depends upon the value of the consumers' outside options.

[79] See also ERG (2009, pp. 22-26) which concludes that there is no strong correlation between penetration or ownership rates and MTRs.

party pays (RPP) at the retail level, so they recover part of their overall costs, including termination costs, from their own retail customers via reception charges (EC 2009b, p. 31). In the European Commission's view, "*RPP may evolve after a reduction of the regulated termination charge or as a response to a Bill and Keep system*", and at least some major European telecoms' operators agree.[80] Ofcom (2009, p. 38), on the other hand, views this as "*highly unlikely, given the likely consumer reaction.*" But Lopez (2008, p.2) argues that the literature on access charges and network competition, such as Berger (2004) (2005), pays too little attention to the fact that networks may charge for receiving calls when MTRs are reduced.[81]

So would the adoption of bill-and-keep lead to reception charges for mobile subscribers, and would this increase or decrease economic efficiency and social welfare? Alternatively, is setting MTRs below marginal cost still optimal in an RPP regime, and if not, how should welfare-optimal termination charges be determined?

The literature on this subject is still in its infancy. Jeon *et al.* (2004, pp. 105-107) analyze duopoly competition with network-based price discrimination and reception charges.[82] Jeon *et al.* (2004, Proposition 9) shows that for $\beta < 1$, in any symmetric equilibrium off-net reception charges are infinite if

$$a \leq \frac{(c_T - \beta c_0)}{(1+\beta)}, \tag{16}$$

and equal to $c_T - a$ otherwise. When $\beta > 1$, reception charges are finite whenever (16) holds, but off-net call prices become infinite when (16) does not hold.

Thus for reasonable parameter values (e.g. $\beta < 1$ and $c_T = c_0$), bill-and-keep leads to reception charges so high that no off-net calls are made. As with call charges, each network strategically chooses high off-net reception charges in order to make the other network less attractive for subscribers. As Jeon *et*

[80] See the responses of Deutsche Telekom, Orange and Telefonica to the European Commission's draft recommendation for example (ec.europa.eu/information_society/policy/ecomm/library/public_consult/termination_rates/index_en.htm).

[81] Since Lopez (2008) assumes equal on-net and off-net retail prices in his model, we do not discuss his paper here.

[82] A potential indeterminacy arises when reception charges are introduced: when call volumes are determined solely by callers, networks are indifferent about the composition of their charges between fixed fees and reception prices, since only their sum matters. Hence there may be a range of (nonequivalent) equilibria. Jeon *et al.* resolve this problem by introducing a random element in receivers' marginal utilities so that both senders' call prices and the reception charges affect call volumes.

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al. put it, "*reception charges provide a second instrument for implementing selective connectivity breakdown: Each network can induce the receiver to hang up off-net calls,*" leading to what they term as *de facto connectivity breakdown* in the symmetric equilibrium.

Hermalin and Katz (2009) consider a duopoly model with on-net/off-net price discrimination and reception charges, in which both sender and receiver utility varies stochastically across calls. Importantly, firms first choose their number of subscribers, and then set prices. This Cournot-like competition effectively decouples competition for market share from the setting of sender and receiver charges, hence the strategic motive for increasing off-net prices is absent in their model. This means that the networks always set off-net sender and receiver prices equal to "perceived" marginal cost, $p_{ij} = c_0 + a$ and $r_{ji} = c_T - a$, respectively (where r_{ji} is the reception charge on network j for receiving a call from network i). Thus if bill-and-keep were adopted ($a = 0$), the total cost of an off-net call would be divided between the sender and receiver in proportion to the costs incurred on each network.

As in the model of Jeon *et al.* (2004), in Hermalin and Katz (2009) firms set on-net sender and receiver prices to maximize surplus on their networks, and the efficient sender and receiver charges typically sum to less than total marginal cost $c_0 + c_T$ (Hermalin and Katz, 2009, Proposition 1). The termination rate cannot be used to induce efficient off-net prices since it does not affect the sum of the off-net sender and receiver prices. Termination charges can still affect efficiency, however, since they determine the allocation of marginal cost between the sender and the receiver of a call. Specifically, if it is relatively likely that different calls generate similar utilities (for both senders and receivers), then the socially optimal termination charge is equal to zero (bill-and-keep). Otherwise the socially optimal termination charge is such that $-c_O \leq a \leq c_T$, and can be either positive or negative.

Thus when firms have a strategic motive to reduce the relative attractiveness of rival networks, as in Jeon *et al.* (2004), network-based price discrimination creates strong incentives for firms to eliminate off-net calls, via high sender or receiver prices, or both. Jeon *et al.* (2004, p. 107) consequently suggest a need for some form of regulation of reception charges, "*in the same way that termination charges cannot just be left to the discretion of the terminating networks.*"

In the Cournot model of Hermalin and Katz (2009), on the other hand, on-net/off-net price differentials result entirely from a failure of networks to internalize the benefits off-net calling creates on other networks, and not from

an attempt to disadvantage a rival firm. The two models therefore lead to strikingly different predictions concerning profit-maximizing sender and receiver charges for given access, or termination, charges. Hermalin and Katz (2009, p. 30) remark that, "*the importance of such cross-carrier effects is an empirical question that remains to be answered.*"

Whatever the theoretical predictions, existing empirical evidence suggests that mobile networks in bill-and-keep countries do not set very high reception charges. Ofcom (2009, Annex 9) presents evidence on sender versus reception charges in the United States, and finds that "*all operators for all levels of output charge the same price for both types of calls.*" And the recent study by Analysys Mason (2008) found that while all bill-and-keep countries have RPP retail charging regimes, there exist free incoming call plans in each of these jurisdictions, and the relative importance of these appears to increase over time (Analysys Mason, 2008, p. 4). Hence, as an empirical matter, it is unclear that adoption of bill-and-keep would necessarily lead to the imposition of significant reception charges for mobile calls.

7 Conclusion

We have argued that efficient pricing on mobile networks requires equal on-net and off-net charges which are below marginal cost, to correct for the call externality. Hence, optimal termination charges are also likely to be below marginal cost, and the difference between MTRs and marginal costs should be larger for mobile-to-mobile charges than for fixed-to-mobile charges, to compensate for more intense strategic competition between mobile networks. High off-net call charges are a distortion in the structure of prices potentially as serious as the distortion in prices that the regulation of mobile termination charges was designed to repair in the first place (i.e. the subsidy of mobile subscription via high termination charges), and are particularly damaging to long-run entry and competition. By increasing mobile networks' incentives to set high on-net/off-net price differentials, the traditional approach to regulating mobile termination rates, based on fully allocated costs (or "long-run incremental cost plus"), may have been doing as much harm as good, reducing welfare and creating a barrier to growth for smaller networks and new entrants.

Our paper thus provides broad support for the significant reductions in MTRs recommended by the European Commission (in EC, 2009a) and, if anything, indicates that even more radical change may be called for. Both the recent theoretical literature, and the available empirical evidence, suggest

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that adopting bill-and-keep for mobile termination rates should result in a more efficient wholesale and retail price structure, help to eliminate barriers to entry caused by "tariff-mediated" network effects, and increase welfare and long-run competition in mobile markets.

A number of arguments against reducing MTRs below marginal cost, or to zero, have received attention in the literature, and been much-aired in recent regulatory debates. These focus on the possibly negative consequences of reducing MTRs for mobile network subscribers considered in isolation, and for mobile subscription, or penetration, rates when network externalities matter. We have shown that these arguments lose much of their force once call externalities, or receiver benefits, are taken into account. Whether a reduction in MTRs will result in an increase or a decrease in welfare and consumer surplus on mobile networks is an empirical question which depends upon the strength of call externalities and the number of firms in the market, amongst other factors. While it is difficult to measure, or observe, the size of call externalities empirically, the evidence we have presented (in Section 3) suggests that they play a significant role in European mobile markets. Arguments that call externalities are likely to be internalized by individuals in stable calling relationships have also been shown to be both unconvincing and inconclusive.

A potentially more difficult question is whether the adoption of bill-and-keep will lead to the introduction of high reception charges for mobile subscribers, and the likely effects of this on economic efficiency and welfare. While the theoretical literature is not in complete agreement on the issue, the available empirical evidence suggests that mobile networks in "bill-and-keep" countries do not charge high prices for receiving calls. Indeed, average call prices tend to be lower, and mobile network usage higher, in "bill-and-keep" as opposed to CPNP regimes.

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