Welfare Analysis of Regulating Mobile Termination Rates in the UK (with an Application to the Orange/T-Mobile Merger)

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03. March 2010

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3 March 2010

Abstract

This paper presents results from a calibrated welfare model of the UK mobile telephony market which includes many mobile networks; calls to and from the fixed network; network-based price discrimination; and call externalities. The analysis focuses on the short-run effects of adopting lower mobile termination rates (MTRs) on total welfare, consumer surplus and profits. Our simulations show that reducing MTRs broadly in line with the recent European Commission *Recommendation* to either "long-run incremental cost"; reciprocal termination charges with fixed networks; or "bill-and-keep" (i.e. zero termination rates), increases social welfare, consumer surplus and networks' profits. Depending on the strength of call externalities, social welfare may increase by as much as £360 million to £2.5 billion per year. The analysis thus lends support to a move away from fully-allocated cost pricing and towards much lower MTRs, with bill-and-keep frequently leading to the highest increase in welfare when call externalities matter. We also apply the model to estimate the welfare effects of the recently-approved merger between Orange and T-Mobile under two different scenarios concerning MTRs.

Key words: telecommunications, regulation, mobile termination rates, network effects, welfare, simulations

JEL Codes: D43, L13, L51, L96

*This article is partly based on research undertaken for Hutchison 3G UK Ltd. The authors are solely responsible for its contents and for the views expressed, however. We are greatly indebted to Adam Mantzos for considerable help in calibrating the current and earlier versions of the model used here.

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1 Introduction

Mobile termination rates (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 a widely-accepted theory, while 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 European regulatory authorities, including Ofcom in the UK, has been to allow for total cost recovery based on fully-allocated cost models.[2] This approach has been increasingly called into question, however, by a new 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.[3] Impetus for change has also come from the entry of new mobile network operators in many European countries, who argue that their growth and profitability have been hampered by high MTRs and the significant levels of on-net/off-net price discrimination adopted by incumbent mobile network operators (MNOs).[4]

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.[5] Following the EC's *Recommendation*, Ofcom published a consultation document (Ofcom, 2009a) which reconsiders the pros and cons of a number of alternative approaches to regulating MTRs. These include: (i) long-run incremental cost pricing (LRIC), broadly the approach recommended

[1] See Armstrong (2002, Section 3.1), Wright (2002) 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 regulates the termination charges of the five UK mobile operators at "long-run incremental cost plus" ("LRIC +"). It treats fixed-to-mobile (FTM) and mobile-to-mobile (MTM) termination charges symmetrically, 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. See Harbord and Pagnozzi (2010).

[3] See, for example, DeGraba (2003); Jeon *et al.* (2004); Berger (2004) (2005); Hoernig (2007); Calzada and Valletti (2008); Hermalin and Katz (2009); Armstrong and Wright (2009b); Cabral (2009); and Hoernig (2009a). Harbord and Pagnozzi (2010) provide a survey of much of this literature.

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

[5] 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.

by the EC;[6] (ii) imposing reciprocity with fixed networks, i.e. setting mobile termination charges to match the regulated rates of fixed-line network operators; and (iii) adopting "bill-and-keep", which would effectively abolish mobile termination charges by setting them equal to zero.[7]

While the first option is in line with the EC's *Recommendation*, reciprocity with fixed networks would also significantly reduce MTRs, since fixed-line operators' regulated termination rates are typically an order of magnitude below those charged by mobile networks. Bill-and-keep represents the most dramatic change in policy, but it has already been adopted in a number of countries (such as the USA, Canada, Hong Kong and Singapore: see Harbord and Pagnozzi, 2010; Analysys Mason, 2008), and was recently recommended by the European Regulators' Group (ERG, 2009).

Ofcom (2009a) discusses the pros and cons of these various approaches in a purely qualitative and largely informal way.[8] The EC's *Recommendation* is also largely based upon purely qualitative argument, although as noted, these arguments have been the subject of a great deal of formal economic modelling in recent years, and the *Recommendation* is broadly consistent with the conclusions which seem to emerge from this new literature.[9] What is lacking, therefore, is a realistic quantitative assessment of the welfare consequences of adopting one or another of the alternatives now being aired. The main purpose in this paper is to provide such an assessment for the UK mobile market.

Building on the standard model employed by nearly all economists to analyze competition, pricing and welfare in network markets such as mobile telephony, we estimate the impact on total welfare, consumer surplus and producer surplus of a decrease in MTRs in the UK market from their current regulated levels to one or another of the alternatives described above. Our quantitative analysis is based on Hoernig (2009b), which provides an analytically tractable model of competition between multiple, asymmetrically-sized mobile networks and allows us to determine both consumer surplus and networks' profits in the imperfectly competitive equilibrium.[10] The main obstacle to applying models of telecommunications competition to real-world markets to date has been the need to assume either a duopoly market, or symmetric firms, since models with several asymmetric networks were considered intractable. Few real-world mobile markets in Europe or elsewhere satisfy either of these assumptions, however. Hoernig (2009b)

[6] Ofcom use the term "long-run marginal cost" (LRMC) to refer to the EC's "LRIC" proposal. Since the EC's terminology corresponds more closely to common usage, we adopt it in this paper.

[7] Each of these alternatives is considered in the EC recommendation. See in particular EC (2009b, p. 29) where it is noted that, "*a significant reduction of termination rates from current levels might create appropriate incentives for voluntary inter-operator agreements and consequently Bill and Keep type arrangements could evolve naturally*".

[8] Ofcom (2007, Annex 19) reports the results of a formal welfare analysis which was intended to provide '*an order of magnitude indication of the consumer welfare gain from regulating MCT charges*'. As Ofcom itself recognized, however (in paragraph A17:15), this analysis is unable to account for such crucial factors as call externalities, imperfect competition and price discrimination, and as such is unsuited to the task of estimating the welfare gains from reducing MTRs.

[9] Section 4 and Annex of EC (2009c) provide the Commission staff's own estimate of the welfare effects of following the *Recommendation*. This calculation is performed at an aggregate level for the whole of the European Union for the period 2007 – 2012, and the resulting welfare gain is found to be at most 1 billion Euros, if not slightly negative. As with Ofcom's 2007 model, this computation is incapable of capturing the effects of call externalities, imperfect competition and asymmetries between mobile operators.

[10] Market Analysis (2008) was an earlier version of this model, but could not separately solve for consumer surplus and network profits, and hence only reported total welfare comparisons. Hoernig (2008) contains many of the ingredients of the current analysis but considers only duopoly networks, with no allowance for fixed-to-mobile and mobile-to-fixed (MTF) calls.

resolves this problem by solving a general model of competition between an arbitrary number of interconnected telecommunications networks with asymmetries in both network and per customer fixed costs. As in Hoernig's (2007) duopoly analysis, the model includes tariff-mediated network externalities, i.e. price discrimination between on-net and off-net calls, call externalities (i.e. receiver benefits), and networks can be asymmetric in size.

We calibrate this model using data pertaining to the UK mobile market, and solve for the (Hotelling) equilibrium tariffs under alternative assumptions concerning the level of MTRs and the importance of the receiver benefits, or call externalities. Our simulation results in Section 4 show that although consumer surplus and economic welfare *may* decrease in the mobile market *considered in isolation* as we reduce the level of MTRs, aggregate welfare *and* consumer surplus increase in the telecommunications market as a whole for all reasonable values of the ratio of receiver to sender benefits (the call externality parameter in our model). Depending on the strength of call externalities, our model predicts market-wide welfare improvements of £360 million to £2.5 billion per annum, with bill-and-keep often resulting in the greatest increase in overall welfare. Inclusion of the fixed-line operator in the analysis is thus indispensable to assessing the economic effects of reductions in MTRs.

A number of recent papers have argued that reducing MTRs will necessarily reduce consumer surplus, and possibly welfare, in the mobile market (Gans and King, 2001, Hoernig, 2008, Armstrong and Wright, 2009a).[11] As we discuss in more detail in Section 5, however, these arguments are incomplete and do not necessarily survive the inclusion of fixed networks, call externalities, and a more realistic number of competing networks in the analysis. It then becomes an empirical question whether a reduction in MTRs will result in an increase or a decrease in welfare and consumer surplus on mobile networks *considered in isolation*. In our simulations, *consumer surplus and welfare increase in both the mobile and fixed markets* when call externalities are significant. Hence, the trade-off between increasing welfare and maintaining consumer surplus in the mobile market disappears once these factors are taken into account.

Our simulation model provides a rigorous and quantifiable approach to assessing the likely consequences of changes in policy towards regulating MTRs, in the UK and elsewhere. Another natural application is to analyze the recently-approved merger between Orange and T-Mobile, which will create a single firm with almost 40% of all UK mobile subscribers. Doing so allows us to predict the merger's effects on economic efficiency, consumer welfare and mobile firms' profits.

We show in Section 6 that with MTRs set at their regulated levels for 2010/11, the overall effect of the merger depends on the strength of call externalities. In the absence of call externalities, the merger *improves* allocative efficiency by moving more subscribers on to a single large network, thus avoiding the inefficiencies associated with high off-net call prices, themselves a product of MTRs which exceed marginal cost. In other words, the merger may help to ameliorate the negative effects of above-cost MTRs as currently allowed by the UK regulatory authorities.

With any significant level of call externalities, this result is reversed by the strategic incentive of the newly merged firm to increase its off-net call prices.[12] Hence there is a critical level of

[11] 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, "*reducing 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*".

[12] It is a standard result of the literature that, in the presence of call externalities, a network's off-net prices are increasing in its own market share. See Jeon *et al.* (2004); Hoernig (2007)(2009b); and Harbord and Pagnozzi (2010).

the call externality parameter for which the merger becomes harmful to allocative efficiency and welfare. When call externalities are large, our simulations predict overall welfare losses from the merger exceeding £1.4 billion per year, dwarfing the cost savings of £390 - £420 million per year predicted by the companies themselves. If we perform our simulations with much lower MTRs, such as those proposed in recent European Commission *Recommendation*, the (negative or positive) effects of the merger on aggregate welfare are much reduced, however.

Since the merger reduces the number of competitors in the mobile market, it reduces the intensity of competition between mobile networks to attract new subscribers. This induces mobile firms to raise the level of their fixed charges, increasing profits at the expense of consumer surplus. The resulting losses in consumer surplus under current MTRs exceed £1.8 billion per annum in the absence of call externalities in our simulations, and up to £2.9 billion per year when the receiver/sender benefit ratio equals one. Even if MTRs were significantly reduced prior to the merger (to bill-and-keep in our simulations), the consumer surplus losses still exceed £1.2 billion per annum for any level of MTRs, as we report in Section 6.2. Although the European Commission has recently approved the merger, subject to certain undertakings agreed by the companies (see EC, 2010), it is difficult to see how these conditions will allay the competition-related concerns illustrated by our simulation model.[13]

Section 2 of the paper describes our underlying Hotelling model, based on Hoernig (2009b). Section 3 details our calibration to UK market data and Section 4 the welfare simulation results. Section 5 discusses our short-run assumptions and considers some longer-run implications of reducing MTRs. Section 6 reports our results on the Orange/T-Mobile merger, and Section 7 concludes.

2 The Model

The model we use is a generalization of the network competition models of Laffont *et al.* (1998) and Carter and Wright (1999)(2003) to include many asymmetric networks. For more details see Hoernig (2009b).[14]

Networks: We assume n mobile networks of different size and one fixed network.[15] Networks face a given fixed cost per subscriber and constant marginal costs for originating and terminating calls. All networks are interconnected and terminate incoming calls at prices given by their respective termination rates. Consumers perceive mobile networks as providing substitutable, differentiated services, hence we consider imperfectly competitive market equilibria in the mobile market. Consumers perceive fixed and mobile networks as providing non-substitutable services, however, so there is no strategic competition between fixed and mobile networks.

[13] These conditions are a revised network-sharing agreement with H3G UK, and an offer to divest 15 MHz of spectrum at the 1800 MHz level.

[14] Several papers have analysed network competition with more than two networks. Symmetric networks are assumed by Calzada and Valletti (2008) and Armstrong and Wright (2009b). Dewenter and Haucap (2005) consider more than two asymmetric networks, but can only solve for the resulting per-minute call prices. Closest to Hoernig (2009b) is Thompson, Renard and Wright (2007), which uses a similar demand specification and considers an arbitrary number of networks. However, networks in their model do not price discriminate between on-net and off-net calls, and no closed-form solution for the equilibrium can be derived.

[15] There are a number of fixed-line networks in the UK, including BT, Virgin Media and Cable and Wireless. BT's share of subscribers in 2008 exceeded 60% (Ofcom 2009b, Table 2). We assume a single fixed-line network here, which sets FTM prices as described immediately below.

Each mobile network's subscriber market share is denoted by $\alpha_i > 0$, $i = 1, ..., n$, with $\sum_{i=1}^{n} \alpha_i = 1$. Mobile network i incurs a yearly fixed cost per customer of f_i, and has on-net call costs of $c_{ii} = c_{oi} + c_{ti}$ per call minute, where the indices o and t stand for origination and termination, respectively. The mobile termination rate (MTR) on network i is denoted a_i, so the cost of an off-net call from network i to network $j \neq i$ is $c_{ij} = c_{oi} + a_j$. The fixed network's termination rate (FTR) is $a_f = c_{tf}$, the cost of call termination on the fixed network. Hence the cost of a call from mobile network i to the fixed network is $c_{if} = c_{io} + a_f$. We only consider calls between the fixed and mobile networks, and neglect other services on the fixed network, including on-net calls.

Tariffs: Mobile networks offer their retail customers a 'bundle' of mobile access, on-net calls, and off-net calls to other mobile networks and to the fixed network. Each mobile network i charges its subscribers an annual subscription fee F_i,[16] and per-minute call prices of p_{ii} for on-net calls and p_{ij} for off-net calls to network $j \neq i$. We assume that mobile networks charge uniform off-net prices to other mobile networks, i.e. $p_{ij} = p_{ik}$ for $j, k \neq i$. The price of calls to the fixed network is denoted p_{if}. We do not consider other services offered by mobile networks, such as international calls, SMS and data services, as their interaction with mobile voice calls is not clear and is likely to evolve over time.[17]

The fixed network charges a per-minute price p_{fm} for calls to mobile networks, which we assume to be equal to the (weighted) average MTR, $\bar{a} = \sum_{i=1}^{n} \alpha_i a_i$, plus a fixed retention rate r_f to cover its cost of origination: hence $p_{fm} = r_f + \bar{a}$.[18]

Consumers: We assume a fixed number of M subscribers in the mobile market, and N subscribers on the fixed network. Each consumer makes calls to all potential recipients on the fixed and mobile networks with equal probability, so in the absence of price differentials we would have a balanced calling pattern. That is, each subscriber on a mobile networks calls all potential receivers with the same probability ρ per one million users, and each fixed network subscriber calls all potential receivers with probability ρ_f per one million users.[19] The demand for call length differs between subscribers on mobile networks and on the fixed network, however.

Networks' customers receive utility from making calls, as a function of call length and the number of calls made. They also obtain utility from receiving calls, independently of their origin, so there is a call externality. Specifically, the utility derived from making, or receiving a call of length q is $u(q)$, or $\beta u(q)$, respectively, where $\beta \geq 0$ measures the strength of the call externality. Given a per-minute price p, consumers demand calls of length $q(p)$, with the resulting surplus of $v(p) = \max_q u(q(p)) - pq(p)$. In the following we will simplify notation by denoting $q_{ij} = q(p_{ij})$, $u_{ij} = u(q_{ij})$, $v_{ij} = v(p_{ij})$ etc., for all $i, j \in \{1, ..., n, f\}$.

A single consumer's surplus from a given tariff is then the sum of his/her net utility from making and receiving calls minus the subscription fee. Consumers make their choice of network based on their own personal preferences for specific networks and the net surplus resulting from the tariffs on offer.

[16] Yearly subscription fees are used without loss of generality in order to simplify notation and because the time frame under consideration is one year.

[17] Ofcom (2007, A19:16) assumes that the corresponding cross-elasticities of demand are small.

[18] The setting of FTM prices in our model follows Ofcom (2007, A19.26).

[19] Since the demand functions calibrated in Section 3 below are linear, the values for ρ and ρ_f can be set arbitrarily as long as ρ/ρ_f remains constant. We have chosen values for these parameters which result in realistic call quantities per subscriber.

A client of network i then obtains the following surplus from making and receiving calls to and from mobile networks and the fixed network:

$$\begin{aligned} w_i &= \rho M \sum_{j=1}^{n} \alpha_j \left(v_{ij} + \beta u_{ji}\right) + \rho N \left(v_{if} + \frac{\rho_f}{\rho} \beta u_{fi}\right) - F_i \\ &= \rho M \sum_{j=1}^{n} \alpha_j h_{ij} + \rho N h_{if} - F_i, \end{aligned}$$

where $h_{ij} = (v_{ij} + \beta u_{ji})$ and $h_{if} = \left(v_{if} + \frac{\rho_f}{\rho} \beta u_{fi}\right)$. In matrix notation, this can be written as[20]

$$w = dMh\alpha + dNh_f - F,$$

where we have introduced the matrix $h = (h_{ij})_{ij}$ and the vectors $w = (w_i)_i$, $\alpha = (\alpha_i)_i$, $h_f = (h_{if})_i$ and $F = (F_i)_i$. Aggregate consumer surplus on mobile networks is then given by

$$S = M\alpha' w.$$

Consumer surplus in the fixed telephony market (FTM and MTF calls) is

$$S^f = N\rho_f M \sum_{i=1}^{n} \alpha_i \left(v_{fi} + \frac{\rho}{\rho_f} \beta u_{if}\right) = N\alpha' \rho_f M g_f,$$

where $g_{fi} = v_{fi} + \frac{\rho}{\rho_f} \beta u_{if}$ and $g_f = (g_{fi})_i$.

Market shares: We assume that consumers consider mobile networks as offering differentiated products in the standard Hotelling fashion, with n firms of unequal size in the market. The resulting expression for market shares is

$$\alpha_i = \alpha_{0i} + \sigma \sum_{j \neq i} (w_i - w_j),$$

where α_{0i} captures ex-ante asymmetries in "brand loyalty", or consumers' valuations of different networks, and $\sigma > 0$ measures the degree of differentiation between operators' offers.[21] In our simulations of short-run effects market shares will be kept constant.

Profits and welfare: Network i's profits are given by

$$\pi_i = M\alpha_i \left(\rho M \sum_{j=1}^{n} \alpha_j R_{ij} + \rho N Q_i + F_i - f_i\right),$$

where $R_{ii} = (p_{ii} - c_{ii}) q_{ii}$ for on-net calls and $R_{ij} = (p_{ij} - c_{ij}) q_{ij} + (a_i - c_{ti}) q_{ji}$ for off-net calls to other mobile networks. Furthermore, $Q_i = (p_{if} - c_{if}) q_{if} + \frac{\rho_f}{\rho} (a_i - c_{ti}) q_{fi}$ are profits from MTF calls and FTM termination. Joint profits of all mobile networks can be written as

$$\Pi = M\alpha' (\rho M R\alpha + \rho N Q + F - f),$$

[20] For these and other mathematical details, consult Hoernig (2009b).

[21] Existence and stability of equilibrium requires that networks be sufficiently differentiated, or that σ is not too large. See Hoernig (2009b, Section 2.2).

where $R = (R_{ij})_{ij}$, $Q = (Q_i)_i$ and $f = (f_i)_i$.

The profits of the fixed network from FTM calls are

$$\pi^f = N\rho_f M \sum_{i=1}^{n} \alpha_i r_f q_f = N\rho_f M r_f q_f.$$

Total welfare is then

$$W = S + S^f + \Pi + \pi^f.$$

Equilibrium outcomes: We model the imperfectly competitive market outcome that will result from mobile networks' offering tariffs such that no single network would like to change its offer given the other offers. The equilibrium outcome determines call prices, subscription fees and the resulting consumer surplus and network profits. It can be shown through standard techniques that equilibrium call prices on mobile networks will take on the following form:

$$\begin{aligned} p_{ii} &= \frac{c_{ii}}{1+\beta}, \\ p_{ij} &= \frac{\sum_{j \neq i} \alpha_j c_{ij}}{1-(1+\beta)\alpha_i}, \; j \neq i, \\ p_{if} &= c_{if}. \end{aligned}$$

Equally, it can be shown that equilibrium fixed fees are given by

$$F = f - dNQ + \rho M \left(\hat{R} - R\right)\alpha,$$

where $\hat{R} = \left(\hat{R}_{ij}\right)_{ij}$ with $\hat{R}_{ij} = 0$ if $i \neq j$ and

$$\hat{R}_{ii} = \frac{1}{\sigma \rho M H_{ii}} - \sum_{j=1}^{n} \frac{H_{ji}}{H_{ii}} R_{ij}.$$

Here we have used $(H_{ij})_{ij} = (I - \sigma d M B h)^{-1} B$ and $B = (B_{ij})_{ij}$, where I is the $(n \times n)$ −identity matrix, and $B_{ii} = n - 1$ and $B_{ij} = -1$ if $i \neq j$. Network i's equilibrium profit is found to be $\pi_i = \alpha_i^2 \rho M^2 \hat{R}_{ii}$, and joint equilibrium profits are $\Pi = \rho M^2 \alpha' \hat{R} \alpha$.

3 The Calibration

The model described in Section 2 above has been calibrated with data from Ofcom (2009a) (2009b) (2009c) (2009d).

Utility and demand parameters: Linear demand functions for mobile-originated calls have been calibrated using data from Ofcom for the year 2008, which was the latest full year available. We assume 76.8 million mobile subscribers (Ofcom, 2009d, Fig. 4.28) who demand 111,000 million call minutes per year (Ofcom, 2009d, Fig. 4.71) at an average per minute price of 5.9 pence per minute (ppm). According to Ofcom (2009d, Fig. 4.58), the average price of a mobile call minute in 2008 was 10.4 ppm, but '*this number is over-stated as it includes the value of the handset subsidy which mobile operators recoup over the duration of the contract'* via monthly subscription charges (Ofcom, 2009d, p. 244). Since we clearly do not wish to include all subscription revenues in the average per minute call price, some means of adjusting this figure must be found. On the one hand, we could argue that the figure should include *no* subscription revenues at all, effectively assuming that contract subscribers behave as if the "free" call minutes included in their contracts were literally free. While some contract subscribers undoubtedly do behave in this way, it seems likely that many implicitly ration their calls to avoid facing "out of bundle" per minute call prices, or the need to purchase more expensive contracts which include a larger number of "free" call minutes.

There is no obviously right way to deal with this issue, so we choose some relatively conservative assumptions. According to data provided in Ofcom (2009d, Fig. 4.22), the average price of a new mobile contract in 2008 was between £300 and £360 annually. Since there were 29.9 million contract customers in 2008 (see Ofcom, 2009d, Fig. 4.43), if we take an average subscription fee of £330 per annum, and assume that one half of this figure is for basic "subscription", then our estimated "per minute" call revenues become £6,567 million, slightly more than half of Ofcom's reported call plus subscription revenues of £11,500 million (Ofcom, 2009d, Fig. 4.39). Dividing this figure by total call minutes results in an average mobile-originated call price of 5.9 ppm.

Linear demand functions for fixed-to-mobile calls have been calibrated using data from Ofcom (2009b) for the year 2008. We assume 33.048 million fixed line subscribers (Table 2) who demand 13,300 million FTM call minutes per year (Table 5), at an average price per minute of 11.7 ppm (Tables 4 and 5).[22]

We assume an elasticity of demand for mobile-originated calls of -0.5, and an elasticity of -0.3 for fixed-to-mobile calls. These are consistent with estimates found in the recent literature, and with those presented to the UK Competition Commission in 2003.[23] Simulation results when we assume an elasticity of demand of -0.3 for both mobile-originated calls and fixed-to-mobile calls are presented in Annex A.

The parameter measuring the strength of call externalities (β) is varied between five levels, from zero (i.e. no call externalities) to the maximal value of 1 (i.e. the receiving party receives the same utility as the sending party). Arguably, a value of at least 0.5 is realistic, even if we allow for some "internalization" of call externalities between individuals in "stable calling relationships" with one another.[24]

Market shares: Mobile subscriptions by network operator for 2008 have been taken from Ofcom (2009d, Figure. 4.42). This results in the subscriber market shares specified in Table 3.1 below.

[22] This figure does not include any subscription revenues.

[23] Dewenter and Haucap (2007) have recently estimated demand elasticities for mobile-originated calls in Austria. They find firm-specific, short-run elasticities between -0.26 and -0.40, and long-run elasticities between -0.46 and -1.1. Various estimates of demand elasticities for mobile originated and fixed-to-mobile calls were presented to the UK Competition Commission's 'calls to mobiles' inquiry in 2003 (see Competition Commission, 2003, Table 8.7). These ranged from -0.48 to -0.8 for mobile originated calls, and from -0.08 to -0.63 for fixed-to-mobile calls. Jerry Hausman submitted estimates for the own-price elasticity of mobile-originated calls of between –0.5 to –0.6 for the USA. Ofcom stated that a reasonable range for the own-price elasticities was between –0.2 and –0.4 for both mobile-originated and fixed-to-mobile calls.

[24] See Harbord and Pagnozzi (2010) for a discussion.

Table 3.1 Subscribers and Market Shares, 2008

	H3G	Vodafone	O2[25]	Orange	T-Mobile[26]
Subscribers (m)	4.5	17.7	21.5	16.4	16.8
Market Shares (%)	5.9%	23.0%	28.0%	21.3%	21.8%

The mobile virtual network operators (MVNOs), such as Virgin Mobile and Tesco Mobile, are not included as independent firms in our analysis.[27] Tesco Mobile is a 50/50 joint venture between Telefónica O2 UK and Tesco plc, and hence acts as a retail arm of O2. Virgin Mobile was originally formed as a joint venture between T-Mobile and the Virgin Group, however in January 2004 the Virgin Group bought out T-Mobile and subsequently became part of the Virgin Media Group in 2006.[28]

Given the networks' market shares, we have chosen a value for the network differentiation parameter (σ) of the underlying Hotelling model in the stable range.[29] The choice of this parameter has no influence at all our overall welfare estimates or comparisons, and relatively little influence on changes in profits and consumer surplus in our comparisons.

Costs on mobile and fixed networks: Ofcom (2007, A19:18) assume fixed costs per mobile subscription of £95.38 per year. We allow for no fixed costs in our model since we only wish to include the avoidable per subscriber costs faced by networks, which are largely composed of handset subsidies. But the level of each mobile network's handset subsidy is determined by the level of their fixed fees in our model, which are themselves a function of the intensity of competition between the networks, and hence the levels of the MTRs. In order to avoid this endogeneity problem we assume that avoidable per-customer fixed costs are zero.

We assume a (long-run) marginal or incremental cost of originating and terminating calls on mobile networks of 1 ppm.[30] Marginal costs of origination and termination on the fixed network are taken from Ofcom (2009c, Table A2.10) which reports termination costs of 0.198 ppm and origination costs of 0.212 ppm. The average level of BT's regulated termination charge in 2008 is 0.207 ppm, which includes an allowance for fixed and common costs.[31] We assume that the fixed network sets the fixed-to-mobile price by charging a fixed retention rate of 6.2 ppm over the average mobile termination rate, derived by subtracting the average mobile termination charge in 2008 from the average retail price of fixed-to-mobile calls.[32]

[25] Includes Tesco Mobile subscribers (1.7 million in December 2008: see www.o2.com/about/tesco_mobile.asp).

[26] Includes Virgin Mobile subscribers (4.76 million, Ofcom, 2009d, Fig. 4.24).

[27] Overall, MVNOs and other service providers using existing mobile networks accounted for 12.7% of mobile subscriptions in 2008 (Ofcom, 2009d, Fig. 4,24).

[28] See http://about.virginmobile.com/aboutus/about/history/.

[29] This parameter has been set at 0.000333 in the simulations reported below.

[30] The French regulator, ARCEP (2008), estimates LRIC on mobile networks to lie between 1 and 2 eurocents per minute (i.e. 0.9 ppm and 1.8 ppm). Hutchison 3G UK Limited (2009, Annex 2) estimates LRIC at approximately 0.5 ppm. Ofcom (2009a, 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*". Hence an assumed long-run marginal or incremental cost of 1 ppm seems reasonable. Experimenting with lower or higher figures makes only minimal differences to our results.

[31] Ofcom (2009c, Table A2.10). This is consistent with Ofcom (2009a), Paragraph 2.18, which states: "*Wholesale FCT charges are currently no more than 0.25 pence per minute. BT's actual FCT charges vary by time of day. The average charges are currently between 0.17ppm and 0.25ppm depending on the point of interconnection and the extent of conveyance (eg single/double tandem)*".

[32] Ofcom (2007, A19.26) follow a similar approach.

In our base scenario, mobile networks' termination rates are set at Ofcom's "LRIC+" levels for 2010/11, the final year of the current price control. These are 4.6 ppm for H3G and 4.3 ppm for the four other mobile operators.[33] The base scenario is then compared with three other scenarios, with MTRs set at: (i) "LRIC" (or "LRMC"); (ii) the average price of termination on the fixed network; and (iii) zero, or bill-and-keep.

4 Simulation Results

This section reports our simulation results, for call externality parameters (β) of 0, 0.25, 0.5, 0.75 and 1, respectively, and for a LRMC value of 1.0 ppm. All results are reported in £ million per calendar year in 2008/09 prices. Increases of the variables under consideration, as compared to the base scenario (LRIC+), are given by positive values and decreases by negative values.[34]

Aggregate effects: As shown in Table 4.1, total welfare, i.e. the sum of social welfare in the mobile and the fixed markets, increases significantly under all three alternative scenarios for MTRs . The extent of the increase depends upon the size of the call externality parameter, and exceeds £2.2 billion per year in all scenarios when β is equal to one, i.e. with equal caller and receiver benefits.

Table 4.1 Change in Welfare Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	367	648	1023	1537	2272
Reciprocal with Fixed	366	675	1086	1651	2459
Bill-and-Keep	360	674	1091	1665	2485

In the absence of call externalities, the increase in aggregate welfare is caused by aligning MTRs more closely to marginal costs, since above-cost MTRs distort call prices upwards and call quantities downwards. Hence, when $\beta = 0$, it is unsurprising that LRMC pricing results in the largest welfare increase.[35] When call externalities matter, welfare-maximizing MTRs are always below cost, however, for two reasons. First, in the absence of strategic effects, below-cost MTRs induce networks to "internalize" call externalities by setting off-net prices below cost. Second, since call externalities create strategic incentives for mobile firms to increase their off-net prices, reducing MTRs below marginal cost mitigates this effect.[36] Hence bill-and-keep increasingly dominates LRMC pricing in welfare terms as we increase β from zero to one.

As discussed in more detail in Section 5 below, reducing MTRs reduces network effects and relaxes price competition in the mobile market. This can result in lower levels of mobile consumer surplus for small values of β. Consumer surplus in the fixed market always increases, however,

[33] These are the final 2010/11 values as determined by the Competition Commission (2009) of 4.3 ppm and 4.0 ppm respectively, indexed by inflation to increase from 2006/07 prices to 2008/09 prices.

[34] The calculations have been performed in Excel. Further details on the simulation model and its results are available from the authors on request.

[35] Because of the distortion in FTM prices caused by the assumed level of fixed retention, this is not necessarily the case. As our simulations with a mobile demand elasticity of -0.3 show (see Table A.1 in Annex A), reducing MTRs below cost can be optimal even when $\beta = 0$, in order to align the FTM price more closely with marginal cost.

[36] See Armstrong and Wright (2009b), Berger (2004) (2005), Hoernig (2008), and Harbord and Pagnozzi (2010).

due to the reduction in the FTM call price. In the absence of call externalities (i.e. $\beta = 0$), the former effect dominates the latter for bill-and-keep and reciprocal termination rates in our simulation, hence aggregate consumer surplus decreases. For $\beta \geq 0.25$ this result is reversed, and for large call externalities (i.e. $\beta = 1$), aggregate consumer surplus increases by more than £1.2 billion in every scenario (see Table 4.2).

Table 4.2 Change in Consumer Surplus Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	29	217	464	800	1276
Reciprocal with Fixed	-31	174	443	810	1328
Bill-and-Keep	-51	157	429	800	1326

Finally, the sum of profits in the fixed and mobile markets increases in all scenarios for any value of β (Table 4.3).

Table 4.3 Change in Profits Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	337	431	558	736	997
Reciprocal with Fixed	397	501	643	841	1131
Bill-and-Keep	411	517	662	864	1159

Summing up, aggregate welfare and profits increase with reductions in MTRs to any of the three alternatives considered, and aggregate consumer surplus also increases when call externalities are significant.

Mobile telephony: We now consider the mobile market in isolation, that is, the effect of reducing MTRs on consumer surplus, welfare and profits from making and receiving MTM calls, and from receiving FTM calls only. According to our simulations, welfare decreases in the mobile market when the call externality parameter β is very low, but increases in all scenarios for $\beta > 0.25$ (see Table 4.4).

Table 4.4 Change in Mobile Welfare Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	-174	107	481	996	1731
Reciprocal with Fixed	-310	-1	410	975	1783
Bill-and-Keep	-352	-38	380	953	1773

The reduction in mobile welfare for low values of β is caused by the reduction in consumer surplus, itself a product of the relaxation in mobile-to-mobile network competition and reduced fixed-to-mobile transfers. With higher levels of call externalities, this effect is reversed (Table 4.5).

Table 4.5 Change in Mobile Consumer Surplus Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	-444	-256	-9	327	802
Reciprocal with Fixed	-623	-418	-149	218	736
Bill-and-Keep	-674	-467	-194	177	702

Mobile networks' profits on the other hand, increase for all levels of β (Table 4.6).

Table 4.6 Change in Mobile Profits Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	270	363	490	669	929
Reciprocal with Fixed	313	417	559	757	1047
Bill-and-Keep	323	429	574	776	1071

Fixed telephony: Finally, we consider the effects of reducing MTRs on the fixed market. The model includes profits and consumer surplus from FTM calls, and also consumer surplus from receiving MTF calls. Fixed termination rates are set at cost, so there are no termination profits. The estimated values for changes in welfare, consumer surplus and profits in the fixed market do not depend on the size of the call externality, since the mobile-to-fixed price is independent of the level of MTRs.

Welfare in the fixed market increases significantly, for two reasons: First, transfers to mobile networks are reduced, and second, FTM call prices are brought closer to their efficient level. Almost all of the increase in welfare on the fixed network is due to the increase in consumer surplus created by lower FTM call prices.

Table 4.7 Change Over "LRIC+" Pricing

	Welfare	Consumer Surplus	Profits
LRMC Pricing	541	473	68
Reciprocal with Fixed	676	592	84
Bill-and-Keep	712	623	88

Profits of the fixed network increase only slightly in our simulations, and this is entirely due to the assumed level of fixed retention (i.e. the fixed network's margin on FTM calls) being applied to a larger number of call minutes. Thus the reduction in transfers to the mobile market accrues entirely to consumers on the fixed network.

5 Short-Run and Long-Run Effects of Reducing MTRs

Our simulations show that although consumer surplus and economic welfare *may* decrease in the mobile market *considered in isolation* when we reduce the level of MTRs, overall welfare, consumer surplus and firms' profits increase in the telecommunications market as a whole, for all reasonable values of the call externality parameter. Depending on the strength of call externalities, our model predicts welfare improvements of £360 million to £2.5 billion per annum, with bill-and-keep often resulting in the greatest increase in overall welfare.[37] Inclusion of the fixed-line operator in the analysis is thus indispensable to assessing the economic effects of reductions in MTRs.

A number of recent papers have argued that reductions in MTRs will necessarily reduce consumer surplus, and possibly welfare, in the mobile market, however, and for two reasons. First, a fixed-to-mobile termination charge above cost results in a flow of termination profits to mobile networks, some or all of which is passed on to mobile subscribers via the "waterbed" effect.[38] 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) have put it, "*high FTM termination charges are a means of transferring surplus from fixed callers to mobile recipients*".

Second, mobile subscribers can also benefit from above-cost mobile-to-mobile termination rates, since high MTM charges 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 subscription charges. 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).[39]

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. Since most telephone subscribers use both fixed and mobile networks, the increase in economic efficiency and welfare achieved by aligning MTRs more closely with marginal costs benefits telephony users in general.[40]

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 a fixed-to-mobile call can be written as

$$s_{fm} = (a - c_t)q_f + \beta u(q_f),$$

where a is the fixed-to-mobile termination rate, c_t the marginal cost of termination, and q_f the length of the call. An increase in a above marginal cost increases the profits of the mobile network, some or all of which is passed on to mobile subscribers via the waterbed effect, but

[37] The corresponding estimates for a mobile demand elasticity of -0.3 are £255 million and £1.4 billion, respectively. By contrast, the EC's maximum estimate was 1 billion euros for the entire European Union for the period 2007 – 2012, as noted above.

[38] The waterbed effect refers to the phenomenon whereby a reduction (or increase) in MTRs leads to a corresponding increase (or reduction) in subscription charges to mobile subscribers. See Armstrong and Wright (2009a, pp. F284-285). Genakos and Valletti (forthcoming) present some empirical evidence on the strength of this effect in twenty countries.

[39] 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 more intense competition created by higher MTRs.

[40] According to data published in Ofcom (2009b, Fig. 4.62, p. 248), 80% of UK households subscribe to both fixed and mobile services.

simultaneously reduces the utility received by the mobile network's subscribers from fixed-to-mobile calls through reducing q_f. With a high ratio of receiver to sender benefits (i.e. the call externality parameter in our model), the latter effect outweighs the former and hence welfare on mobile networks becomes a decreasing function of the level of MTRs.[41,42]

The argument that above-cost, mobile-to-mobile termination rates benefit mobile consumers is also incomplete. As demonstrated by Hoernig (2009b), it is only necessarily true in models with two mobile networks. 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.

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. In our simulations, when call externalities are significant *consumer surplus and welfare increase in both the mobile and fixed markets*. Hence, the trade-off between increasing welfare and maintaining consumer surplus in the mobile market disappears once call externalities and a realistic number of networks are taken into account.

Our simulation model thus provides a rigorous and quantifiable approach to assessing the likely short-run effects of changes in MTRs, taking account of call externalities, calls to and from the fixed network, and a realistic number of firms. Nevertheless, our model assumes that the size of the market (i.e. the total number of mobile subscribers), mobile networks' market shares, and the structure of retail prices remain constant. We now consider each of these longer-run issues in turn.[43]

Market expansion argument: Mobile operators in Europe have long argued that high MTRs 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.[44]

Armstrong and Wright (2009a) have recently provided some theoretical support for this policy. Noting that mobile subscribers' utility increases with both the fixed-to-mobile and mobile-

[41] See Armstrong and Wright (2009b) and Harbord and Pagnozzi (2010, Section 5.1) for further discussion.

[42] 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 (forthcoming).

[43] Our simulation model also assumes that the markets for fixed-to-mobile and mobile-to-mobile calls are separate, while in reality most consumers have access to both types of network and are able to substitute between the two types of call. Armstrong and Wright (2009a) consider this issue, and conclude that high termination rates for FTM calls lead consumers to substitute MTM for FTM calls. Thus a reduction in FTM termination rates will result in a rebalancing of calls originating on fixed and mobile networks, increasing the proportion of the former. Ofcom (2007, p. 391) assumed that the relevant cross-elasticities of demand were small.

[44] Since the Competition Commission's 2003 inquiry, mobile firms in the UK have received a "network externality surcharge" on top of their regulated MTRs for this purpose. See Competition Commission (2003, pp. 225-252). In its 2008/09 inquiry, the Competition Commission revisited the issue and decided that a network externality surcharge was no longer justified (see Competition Commission, 2009, Section 4). 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.

to-mobile termination charges in their duopoly 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 mobile 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. 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.[45]

As discussed immediately above (see also Harbord and Pagnozzi, 2010, Section 5), 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 maximizes surplus on mobile networks can be above or below marginal cost, and even below zero. Whether fixed-to-mobile termination rates can be used to increase mobile take-up is therefore 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 overall. In theory at least, it could equally well be that MTRs below marginal cost are required to induce market expansion.

Further doubt is cast on the market expansion argument by evidence on mobile subscription, or penetration, rates in bill-and-keep countries versus "calling party network pays" (CPNP) countries with higher MTRs. Recent studies undertaken for Ofcom (Ofcom 2009a, 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 subscription levels do not appear to depend strongly on the level of MTRs.[46]

Market shares: Our second assumption, that market shares remain constant, can also be questioned. Although the model of Hoernig (2009b) recomputes equilibrium market shares following changes in MTRs, building *ex ante* asymmetry in market shares into the model requires fixing an "asymmetry parameter", which should itself be a function of the level of MTRs in the long run. Hence there is little loss of generality in setting the short-run market shares directly, and this simplifies the model's calculations.

In the longer run, however, reducing MTRs should reduce barriers to entry and growth for smaller networks, and this may result in the equalization of market shares over time. As

[45] Armstrong (2002), Wright (2002) 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.

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

numerous authors have observed, above-cost MTRs exacerbate the network effects associated with "tariff-mediated network externalities", by increasing mobile networks' strategic incentives to set high on-net/off-net price differentials, and this is to the detriment of smaller networks and new entrants.[47] As described by Armstrong and Wright (2009b, p. 95):

> *".... High MTM charges may deter entry or induce exit of a smaller mobile rival. By setting above-cost MTM termination charges, the incumbent networks can induce network effects which make entry less attractive for the newcomer. With high MTM charges, off-net calls will be more expensive, which particularly hurts a small network since the bulk of its subscribers' calls will be off-net. An additional effect of high off-net call prices will be to reduce the number of calls received by a small network's subscribers, thereby further reducing its ability to compete when call externalities are important."*

A move to much lower MTRs, or bill-and-keep, should therefore result not only in a more efficient wholesale and retail price structure in the short run, as represented in our model, but also eliminate barriers to entry in the mobile market, and result in a medium to long-run tendency for networks' market shares to equalize. If this competition-increasing effect were found to be large, our model may significantly underestimate the longer-run benefits for consumers of reducing MTRs.

Receiving party pays: Finally, reducing the level of MTRs may affect the types of tariffs offered by mobile networks. 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 party pays (RPP), and Lopez (2008, p.2) argues that the existing literature pays too little attention to the fact that networks may charge for receiving calls when MTRs are reduced.[48] So would the reductions in MTRs considered in this paper lead to reception charges for mobile subscribers, and would this increase or decrease economic efficiency and social welfare?

The literature on this subject is still in its infancy, so no definite answer can be given. Jeon *et al.* (2004, pp. 105-107) analyze duopoly competition with network-based price discrimination and reception charges, and show that for $\beta < 1$, in any symmetric equilibrium off-net reception charges are either infinite or equal to $c_t - a$ depending on parameter values. For reasonable parameter values, bill-and-keep can lead to reception charges so high that no off-net calls are made. Hermalin and Katz (2009), on the other hand, consider a Cournot model in which the strategic motive for increasing off-net prices is absent, implying that 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. The two models therefore lead to strikingly different predictions concerning profit-maximizing sender and receiver charges for given access, or termination, charges, and Hermalin and Katz (2009, p. 30)

[47] See Armstrong and Wright (2009b); Cabral (2009), Calzada and Valletti (2008); Hoernig (2007) (2009a); and Harbord and Pagnozzi (2010).

[48] See EC (2009b, p. 31). In the EC's view, "*RPP may evolve after a reduction of the regulated termination charge or as a response to a Bill and Keep system*". Ofcom (2009a, p. 38), however, views this as "*highly unlikely, given the likely consumer reaction.*"

remark that, "*the importance of such cross-carrier effects is an empirical question that remains to be answered*".

Whatever the theoretical predictions, as noted by Harbord and Pagnozzi (2010, Section 6), 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.

6 Analysis of the Orange/T-Mobile Merger

Another application of our simulation model is to analyze the recently-approved merger between Orange and T-Mobile in the UK. The merger will create a firm with at least 37% of all UK mobile subscribers, and increase the market's Herfindahl-Hirschman Index (HHI) from just over 2083 to just over 2750. Our model allows us to predict the merger's unilateral effects on economic efficiency, consumer welfare and mobile firms' profits.

So as not overestimate any positive or negative effects of the merger, we now assume that there are six independent mobile competitors in the market, by including Virgin Mobile as an independent firm, with the pre - and post-merger subscriber numbers and market shares specified in Table 6.1 below (see Section 3 above for details). This is a conservative assumption, since the arrangement between T-Mobile and Virgin Mobile probably means that the two firms are not entirely independent of each other as retail competitors.[49]

Table 6.1 Subscribers and Market Shares, 2008/09

	H3G	Vodafone	O2	Orange	T-Mobile	Virgin
Subscribers (m)	4.5	17.7	21.5	16.4	15.7	4.76
Pre-Merger Market Shares (%)	5.9%	23.0%	28.0%	21.3%	15.7%	6.2%
Post-Merger Market Shares (%)	5.9%	23.0%	28.0%	37.0%		6.2%

Given the networks' market shares, we have calibrated the value for the network differentiation parameter (σ) of the underlying Hotelling model for each value of the call externality parameter (β). The resulting values are those given in Table 6.2.[50] The choice of this parameter has no influence at all on our pre-merger and post-merger aggregate welfare comparisons, but does effect the comparison of profits and consumer surplus in our simulations.[51]

[49] The companies themselves assume that Virgin Mobile is an independent network when reporting their post-merger market share.

[50] We have calibrated the value of σ for each value of β so that our model "predicts" the same level of mobile call plus subscription revenue in 2008 as reported by Ofcom (2009d, Fig. 4.39), for 2008 MTRs and annual per-customer fixed costs of £95.38 (as reported by Ofcom, 2007, A19:18).

[51] All other assumptions in the model are carried over from the welfare analysis, as described in Section 3 above. Merger simulation results when we assume an elasticity of demand of -0.3 for both mobile-originated calls and fixed-to-mobile calls are presented in Annex C.

Table 6.2 Network Differentiation Parameter

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
$\sigma =$	0.001063	0.001015	0.000962	0.000901	0.000832	0.000754

We simulate the effects of the merger under two different assumptions concerning the level of MTRs. In Section 6.1, the mobile networks' MTRs are set at Ofcom's estimates of "LRIC+" for the final year of the current price control 2010/11, adjusted for inflation to 2008/09 prices.[52] In Section 6.2 the mobile networks' MTRs are set at zero (i.e. bill-and-keep) prior to the merger. All reported results are stated in £ million per calendar year in 2008/09 prices. Increases of the variables under consideration are given by positive values and decreases by negative values.

6.1 Effects of the Merger under 2010/11 MTRs

With MTRs set at their regulated levels for 2010/11, the overall effects of the merger depend on the strength of call externalities, or receiver benefits. In the absence of call externalities ($\beta = 0$), the merger *improves* allocative efficiency and welfare by moving more subscribers on to a single large network, thus avoiding the inefficiencies associated with high off-net call prices. As call externalities become significant, however, this result is reversed by the strategic incentive of the newly merged firm to increase its off-net call prices. Hence there is a critical level of β for which the merger becomes harmful to allocative efficiency and welfare. In our simulations, this always occurs when β is between one fifth and two fifths. For $\beta = 1$, our model predicts overall welfare losses from the merger exceeding £1.4 billion per year, dwarfing the cost savings of £390 - £420 million per year predicted by the companies themselves.[53]

Table 6.3 Merger with 2010/11 MTRs

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
Change in Welfare	24	6	-56	-210	-573	-1,465
Change in Consumer Surplus	-1,821	-1,883	-1,982	-2,142	-2,418	-2,932
Change in Profits	1,845	1,889	1,926	1,932	1,844	1,467

Even for moderate values of β, such as three fifths, the model predicts a welfare loss of approximately £210 million per year, and this increases rapidly to £573 million per year when β reaches four fifths. Hence for moderate to high call externalities the merger would appear to be detrimental to economic efficiency, even if we allow for all of the cost savings posited by the companies.

In addition, the merger reduces the intensity of competition between the mobile networks, which induces them to raise the level of their fixed charges, increasing profits at the expense of consumer surplus. This results in losses in consumer surplus exceeding £1.8 billion per annum when β is equal to zero, increasing to more than £2.9 billion per year when β equals one.

[52] As in Section 4 above, these are the final 2010/11 values as determined by the Competition Commission (2009) of 4.3 ppm and 4.0 ppm respectively, indexed by inflation to increase from 2006/07 prices to 2008/09 prices. This results in MTRs of 4.3 ppm for Vodafone, O2, T-Mobile and Orange, and 4.6 ppm for H3G.

[53] Our estimate of the merger's expected annual cost savings is based on information provided in Orange and T-Mobile (2009). The calculations are detailed in Annex B. It is not clear that any of the cost savings claimed by the companies are of a type that would lead to reductions in prices for consumers, since they neither effect marginal costs nor avoidable per subscriber costs. Hence they may not be taken into account by European competition authorities. See, for example, EC (2004, Section VII).

6.2 Effects of the Merger under Bill-and-Keep

If we perform our simulations with much lower MTRs, such as those proposed in the recent European Commission *Recommendation*, the (negative or positive) effects of the merger on aggregate welfare are much reduced. The merger's effects on consumer surplus, however, vary depending on the effects of the reduction in MTRs on market shares. We consider two possibilities. First, we assume that bill-and-keep is adopted prior to the merger, with no (short-run) effect on network market shares. In this case, with very low receiver/sender benefit ratios ($\beta < 0.4$) the merger improves allocative efficiency by just over £2 million per year, but this welfare gain falls to zero when β reaches one half (see Table 6.4a). The maximum welfare loss of just over £29 million per year occurs when β is equal to one. If we allow for the companies' claimed cost savings of £390 - £420 million per year, this means that the merger will be welfare improving for all reasonable values of the call externality parameter.

But the merger still results in large decreases in consumer surplus for all values of β, from £1.98 billion per annum when $\beta = 0$ to £2.74 billion per year when $\beta = 1$. Hence even if a regime of very low MTRs were adopted, such as bill-and-keep, the merger creates significant welfare losses for consumers.

Table 6.4a Short-run Effects of Merger under Bill-and-Keep

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
. Change in Welfare	2	2	1	-1	-8	-29
Change in Consumer Surplus	-1,983	-2,065	-2,171	-2,309	-2,491	-2,743
Change in Profits	1,985	2,067	2,172	2,308	2,483	2,715

The adoption of bill-and-keep should result in a medium to long-run tendency for networks' market shares to equalize, however, due to the relationship between MTRs, 'tariff-mediated network externalities' and positive or negative network effects. A reduction of MTRs to zero effectively eliminates the competitive advantage of larger networks, and this should promote growth by smaller networks.[54] To capture this, we assume that network's market shares are equalized both before and after the merger (see Table 6.4b). In this case, the merger's effect on aggregate welfare ranges from just over £1 million per year (when $\beta = 0$), to minus £2 million per year (when $\beta = 1$). The effect on consumer surplus is also somewhat ameliorated, and varies between minus £1.2 billion per year (when $\beta = 0$), to minus £ 1.7 million per year (when $\beta = 1$).

Table 6.4b Merger under Bill-and-Keep with Market Share Symmetry

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
Change in Welfare	1	1	1	0	-1	-2
Change in Consumer Surplus	-1,220	-1,270	-1,335	-1,420	-1,533	-1,689
Change in Profits	1,221	1,271	1,336	1,421	1,533	1,686

6.3 Discussion

Our analysis shows that with MTRs set at their regulated levels for 2010/11, the aggregate effects of the Orange/T-Mobile merger depend on the strength of call externalities. The merger

[54] 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, 2009, p. F286).

improves allocative efficiency and welfare in the absence of receiver benefits by moving more subscribers on to a single large network. This observation provides a stark illustration of the inefficiencies created by the current approach to regulating MTRs. In the absence of call externalities, efficiency and welfare (although not consumer surplus) would be increased even further by a merger of all five of the mobile network operators in the UK market into a single monopoly network, so that all mobile-to-mobile calls became more efficiently-priced on-net calls. When receiver benefits matter, this is result is reversed, so there is a critical level of the call externality parameter for which the merger becomes harmful to allocative efficiency.

Under bill-and-keep, these aggregate effects on welfare and efficiency are much reduced, since off-net call prices are much closer to their efficient level once MTRs are set at zero. Nevertheless, the merger significantly reduces competition and consumer surplus in each of the scenarios we have considered. With the 2010/11 levels of regulated MTRs, these losses exceed £1.8 billion per annum in the absence of call externalities, and £2.9 billion per year when β equals one. Under bill-and-keep, the consumer surplus losses still exceed £1.2 billion per annum for any level of MTRs, even once we allow for a longer-run tendency for networks' market shares to equalize.

The European Commission has recently approved the merger, subject to certain undertakings agreed by the companies relating to network-sharing arrangements and divestiture of spectrum (see EC, 2010). It is not obvious how these undertakings address the competition and welfare-related concerns illustrated by our simulation model, however.

7 Conclusion

The regulation of mobile termination rates based on fully-allocated costs (or "long-run incremental cost plus"), results in regulated MTRs an order of magnitude above reasonable estimates of long-run incremental, or marginal, costs on mobile networks. In the presence of call externalities, efficient pricing on mobile networks requires MTRs below marginal cost, and this has led to increasing calls for reform (for example, Harbord and Pagnozzi, 2010). The European Commission's 2009 *Recommendation* represents a radical shift in regulatory policy, which may ultimately lead to the abolition of MTRs altogether. While the recent theoretical literature provides some qualitative support for this change in policy, in this paper we have provided a rigorous and quantifiable approach to assessing the effects of significant reductions in MTRs in the UK mobile market, and elsewhere.

Our simulations show that reducing MTRs broadly in line with the European Commission's recommendation increases social welfare, consumer surplus and networks' profits in the UK mobile market. Depending on the strength of call externalities, social welfare may increase by as much as £360 million to £2.5 billion per year. In addition, contrary to claims made in the recent literature, our simulations confirm that reducing MTRs can also benefit mobile subscribers considered in isolation in oligopoly markets, especially when call externalities are significant. Our short-run welfare analysis thus lends support to a move away from fully-allocated cost pricing and towards much lower MTRs, with bill-and-keep often resulting in the largest increase in overall welfare. Reducing mobile termination rates should not only result in a more efficient wholesale and retail price structure in the short run but, by eliminating barriers to entry caused by "tariff-mediated network effects", increase competition and welfare in mobile markets in the longer run.

We have also analyzed the likely effects of the merger between Orange and T-Mobile, and shown that its overall effect on efficiency depends on the strength of call externalities, when MTRs are set at the their current, regulated levels. The adoption of bill-and-keep should ameliorate these aggregate welfare effects, although serious concerns about the merger's negative impact on consumers remain. The undertakings agreed between the companies and the European Commission do not appear to address these concerns.

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Annex A Welfare Simulations with a Mobile Demand Elasticity of -0.3

This annex reports aggregate simulation results for call externality parameters (β) of 0, 0.25, 0.5, 0.75 and 1, respectively, and for a LRMC value of 1.0 ppm when we assume a demand elasticity of -0.3 for both FTM and MTM calls. All reported results are stated in £m per calendar year in 2008/09 prices. Increases of the variables under consideration, as compared to the base scenario, (LRIC+) are given by positive values and decreases by negative values.

Aggregate effects

Table A.1 Change in Welfare Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	255	434	668	987	1438
Reciprocal with Fixed	260	458	716	1067	1563
Bill-and-Keep	258	459	722	1078	1582

Table A.2 Change in Consumer Surplus Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	-38	81	234	440	729
Reciprocal with Fixed	-89	41	209	434	748
Bill-and-Keep	-105	27	197	425	743

Table A.3 Change in Profits Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	293	353	434	546	709
Reciprocal with Fixed	349	417	507	633	815
Bill-and-Keep	363	432	524	653	839

Mobile telephony

Table A.4 Change in Mobile Welfare Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	-287	-108	127	446	897
Reciprocal with Fixed	-416	-218	40	391	887
Bill-and-Keep	-454	-253	10	366	871

Table A.5 Change in Mobile Consumer Surplus Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	-512	-393	-239	-33	255
Reciprocal with Fixed	-681	-551	-383	-159	156
Bill-and-Keep	-728	-597	-427	-199	120

Table A.6 Change in Mobile Profits Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
LRMC Pricing	225	285	366	479	642
Reciprocal with Fixed	265	333	423	549	731
Bill-and-Keep	275	344	437	565	751

Fixed telephony

Table A.7 Change Over "LRIC+" Pricing

	Welfare	Consumer Surplus	Profits
LRMC Pricing	541	473	68
Reciprocal with Fixed	676	592	84
Bill-and-Keep	712	623	88

Annex B Efficiency Gains from the Orange/T-Mobile Merger[55]

Orange and T-Mobile forecast efficiency gains totalling £545m a year from 2015 onwards.[56] However in the preceding years 2010 to 2014, forecast annual gains are generally lower than this due to implementation costs and the phasing in of savings. Orange and T-Mobile forecast:

- annual operating expenditure (opex) savings of £445m from 2014 onwards;
- the phasing in of opex savings at 15% of £445m in 2010, 75% of £445m in 2012, and 100% of £445m in 2014;
- opex integration costs to net off these savings totalling between £600m and £800m between 2010 and 2014;
- annual net capital expenditure (capex) savings of £100m from 2015 onwards;
- total net capex savings of £620m between 2010 and 2014; and
- a Net Present Value (NPV) of over £3.5bn in net savings.

We have used this information to estimate the equivalent level annuity which would match these efficiency gains, i.e. a constant per annum net saving which delivers the same NPV as the variable profile of savings described above.

We do not know the forecasting horizon over which the NPV of £3.5bn has been calculated, nor do we know some of the detailed cashflow assumptions used to calculate that NPV (e.g. phasing of opex savings in 2011, precise level of integration costs). We have therefore developed a range of annuity estimates for each of two assumed forecasting horizons: 25 years and 100 years. In each case, we have calculated the level annuity equivalent to a high gain scenario,

[55] We are grateful to Adam Mantzos for preparing this annex.

[56] All figures sourced from the presentation, *Combination of Orange UK & T-Mobile UK: Creating a new mobile champion*, Orange and T-Mobile, 8 September 2009.

where the detailed assumptions are assumed to deliver relatively high gains within the envelope provided by the available information (e.g. opex savings in 2011 assumed at 50% of £ 445m, integration costs assumed at £600m); and a low gain scenario at the other extreme (e.g. opex savings in 2011 assumed at 30% of £ 445m, integration costs assumed at £800m).

For each scenario, we have calculated the discount rate that would generate an NPV of £3.5bn for the given forecasting horizon and set of detailed assumptions, and then calculated the level annuity which, over that same forecasting horizon, would also generate an NPV of £3.5bn.

Our results are shown below:

Equivalent level annuity (£m)	High gain	Low gain
25 year horizon	410	388
100 year horizon	419	399

Annex C Merger Simulations with a Mobile Demand Elasticity of -0.3

We have re-calibrated the value for the network differentiation parameter (σ) for each value of the call externality parameter (β) for a demand elasticity of -0.3. The resulting values are those given in Table C.0[57]

Table C.0 Network Differentiation Parameter

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
$\sigma =$	0.001057	0.001026	0.000990	0.000949	0.000901	0.000843

All reported results are stated in £m per calendar year in 2008/09 prices. Increases of the variables under consideration are given by positive values and decreases by negative values.

Effects of the Merger under 2010/11 MTRs

Table C.1 Merger with 2010/11 MTRs

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
Change in Welfare	14	4	-34	-126	-344	-879
Change in Consumer Surplus	-1,857	-1,893	-1,950	-2,043	-2,203	-2,500
Change in Profits	1,871	1,896	1,917	1,917	1,859	1,621

[57] Calibrated for each value of β so that the model "predicts" the same level of mobile call plus subscription revenue in 2008 as that reported by Ofcom (2009d, Fig. 4.39), in the presence of 2008 MTRs and an annual per-customer fixed cost of £95.38 as reported by Ofcom (2007, A19:18).

Effects of the Merger under Bill-and-Keep

Table C.2a Merger under Bill-and-Keep

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
Change in Welfare	1	1	1	-1	-5	-17
Change in Consumer Surplus	-1,993	-2,043	-2,108	-2,192	-2,303	-2,456
Change in Profits	1,994	2,045	2,109	2,192	2,298	2,438

Table C.2b Merger under Bill-and-Keep with Market Share Symmetry

	$\beta = 0$	$\beta = 0.2$	$\beta = 0.4$	$\beta = 0.6$	$\beta = 0.8$	$\beta = 1$
Change in Welfare	1	1	0	0	0	-1
Change in Consumer Surplus	-1,225	-1,256	-1,296	-1,348	-1,417	-1,512
Change in Profits	1,226	1,257	1,297	1,348	1,417	1,510