WELFARE ANALYSIS OF REGULATING MOBILE TERMINATION RATES IN THE UK*

DAVID HARBORD† STEFFEN HOERNIG‡

forthcoming in the *Journal of Industrial Economics*

May 9, 2014

Abstract

We develop a calibrated simulation model of the UK mobile telephony market and use it to analyze the effects of reducing mobile termination rates (MTRs) as recommended by the European Commission. We find that reducing MTRs is likely to increase both consumer surplus and networks' profits. Depending on the strength of call externalities (i.e., benefits to the recipient of a call), social welfare may increase by as much as £1 billion to £4.6 billion per year. We also use the model to estimate the welfare effects of the 2010 merger between Orange and T-Mobile and find that the merger led to a substantial reduction in consumer surplus.

*We thank Lars Wiethaus, Sjaak Hurkens, seminar audiences at EARIE (Istanbul), the University of Évora, ZEW (Mannheim), and the Portuguese Competition Authority, the Editor and two anonymous referees for extremely helpful comments and suggestions which have greatly improved the paper.

†Market Analysis Ltd., 34 Great Clarendon Street, Oxford OX2 6AT, UK (e-mail: davidharbord@market-analysis.co.uk).

‡Nova School of Business and Economics, Universidade Nova de Lisboa, Campus de Campolide, 1099-032 Lisbon, Portugal (e-mail: shoernig@fe.unl.pt).

I 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. In the UK, the regulation of MTRs has been the subject of intense controversy for more than a decade now. According to the prevailing theory (see Armstrong and Wright [2009a]; Armstrong [2002, Section 3.1]; and Wright [2002]), while competition between mobile networks to attract new customers may be fierce, in the absence of regulation they will still charge monopoly-level prices to other networks for terminating calls to their subscribers. Once a consumer subscribes to a particular mobile firm, callers on fixed telephone and other mobile networks must send their calls to that subscriber's chosen network. No matter how competitive the market for mobile subscribers may be, a mobile network holds a monopoly over, and can charge high prices for, delivering calls to its own subscribers.[1] Concerns about mobile call termination being a bottleneck service, and a history of high termination charges, led to MTRs being regulated for the first time in the UK in 1999, and they have since been subject to price controls in every country in the European Union, and in numerous other countries around the world.[2]

Until 2011, the approach to regulating MTRs adopted by European regulatory authorities, including the telecoms regulator Ofcom in the UK, allowed for total cost recovery based on fully-allocated network cost models.[3] This approach was called into question, however, by an economic literature highlighting the two-sided nature of mobile-to-mobile interconnection and the significant role that call externalities, i.e. receiver utilities, play in the analysis of competition, equilibrium pricing, and entry in these markets.[4] As observed by Hermalin and Katz [2011], "*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

[1]The characterization of mobile call termination as a monopoly or "bottleneck" service implicitly 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]In contrast, in the United States and Canada, as well as in Singapore, Hong Kong and China, something close to Bill & Keep has been adopted for mobile termination, under which MTRs are set at (or near) zero at the wholesale level. In these countries mobile subscribers are also often charged for receiving calls. See OECD [2012].

[3]See Appendix A for a more detailed discussion of UK regulatory policy towards MTRs.

[4]See, for example, DeGraba [2003]; Jeon *et al.* [2004]; Berger [2004, 2005]; Hoernig [2007, 2009]; Calzada and Valletti [2008]; Hermalin and Katz [2011]; Armstrong and Wright [2009b]; and Cabral [2011]. Harbord and Pagnozzi [2010] provide a survey of much of this literature.

efficiently internalizes the two-sided benefits. This requires an analysis which balances a number of competing effects, and may imply welfare-maximizing MTRs below marginal cost, and even less than zero.

High mobile-to-mobile termination charges exacerbate mobile networks' incentives to set high on-net versus off-net call price differentials, i.e. large differences between the prices for calls made on the subscriber's own network versus calls made to rival networks. These create "tariff-mediated network effects" (Laffont, Rey and Tirole [1998b]) which benefit larger networks and cause firms to compete more intensely for subscribers, thus benefitting mobile consumers via lower subscription charges (the "network competition effect").[5] At the same time, higher MTRs reduce consumer surplus through higher off-net call prices, and this effect is stronger when receiver benefits are large (the "call externality effect"). Finally, high fixed-to-mobile termination charges are a means of transferring surplus from fixed network callers to mobile subscribers, since termination of calls from fixed networks provides mobile operators with profits which are at least partially competed away in the mobile market (the "waterbed effect").[6] Although a number of authors have recently argued that reducing MTRs will necessarily harm mobile subscribers, as we discuss immediately below this is only true in special cases. In more realistic settings, the welfare effects of changes in MTRs are ambiguous, and depend upon the strength of call externalities and market structure.

The debate in the UK and Europe over the regulation of MTRs was fiercely contested but suffered from a lack of any serious quantitative assessment of the likely effects of regulating MTRs on prices, welfare, and consumer and producer surplus in telecommunications markets. In 2009, the European Commission (EC [2009a]) proposed dramatic reductions in mobile access charges, and Ofcom subsequently published a consultation document (Ofcom [2009a]) considering the pros and cons of three alternative approaches to regulating MTRs. These were: (i) pricing at "pure long-run incremental cost" ("pure LRIC"), broadly the approach recommended by the EC; (ii) imposing reciprocity with fixed networks, i.e. setting mobile termination charges to match the regulated rates of fixed-line network operators, as practised in the USA; and (iii) adopting Bill & Keep (B&K), which would effectively abolish mobile termination charges by setting them equal

[5] Appendix A provides some evidence on the extent of historical on-net/off-net price discrimination in the UK mobile market.

[6] This expression, attributed to Paul Geroski, describes a multiple good firm's optimal reaction to increase some prices if some other price is forced down, just as pressing down one side of a waterbed pushes up its opposite side. In the context of mobile markets, this is usually understood as lower termination rates leading to higher customer subscription charges.

to zero.[7] While these proposals represented a fundamental reversal in regulatory policy, both Ofcom and the European Commission discussed the merits and demerits of the various approaches to regulating MTRs in a purely qualitative and largely informal way. What has been lacking is a rigorous quantitative framework that allows us to evaluate the welfare consequences of adopting one or another of the alternatives proposed.

The principal purpose of this paper is to provide such a framework and assessment for the UK mobile market. We present an analytically tractable model of competition between multiple mobile networks with asymmetries in market shares and costs which allows us to estimate the impact on total welfare, consumer surplus and producer surplus of a decrease in MTRs in the UK mobile market from their 2010 levels to one or another of the alternatives described above. Our model, which builds on Hoernig [2014], overcomes the limitations of earlier models, and allows for a more realistic quantitative assessment of changes in regulatory policy towards interconnection pricing than had previously been possible.[8]

We calibrate the key demand and preference parameters of the model using data from the UK mobile market allowing for four mobile networks, calls to and from the fixed network, network-based price discrimination, and call externalities, and solve for the equilibrium multi-part tariffs under alternative assumptions concerning the level of MTRs and the ratio of receiver to sender benefits (the call externality parameter in our model). Our simulations, reported in Section IV.1, indicate 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 call externality parameter. Depending on the strength of call externalities, our simulations predict market-wide welfare improvements of £1 billion to £4.6 billion per annum, with Bill & Keep resulting in the greatest increase in overall welfare.

As noted above, a number of recent papers have argued that reducing MTRs will reduce consumer surplus, and possibly welfare, in the mobile market (Gans and King [2001]; Armstrong and Wright [2009a]). Specifically, the argument is that high *fixed-to-mobile*

[7] In 2011 Ofcom published a decision (in Ofcom [2011a]) requiring UK mobile operators to reduce MTRs from values which then exceeded 4.15 pence per minute (ppm) to its estimate of "pure LRIC" of 0.72 ppm by 2015. Following an appeal by the companies, the UK´s Competition Commission recommended slightly deeper reductions to 0.65 ppm and a shorter transition period (Competition Commission [2012]). See Appendix A.

[8] 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.

termination charges create profits for mobile firms, some or all of which are passed on to mobile subscribers via the "waterbed effect".[9] Hence mobile subscribers should prefer fixed-to-mobile termination rates set at the monopoly (i.e. profit-maximizing) level. In addition, mobile subscribers may benefit from high *mobile-to-mobile termination rates,* due to the tariff-mediated network effects mentioned above (the network competition effect). The oft-cited result is that equilibrium consumer surplus on mobile networks is increasing in the level of the mobile-to-mobile termination rate.[10]

While these arguments have been much aired in recent regulatory debates, as we discuss in more detail in Section 4.1 they are subject to a number of important caveats and do not necessarily survive the inclusion of call externalities and a more realistic number of competing networks in the analysis. As concerns fixed-to-mobile termination rates, the gain to mobile subscribers from low subscription charges is always outweighed by the welfare loss due to higher call prices on the fixed network. Second, with a high ratio of receiver to sender benefits, welfare on mobile networks becomes a decreasing function of the level of MTRs.

The argument that high mobile-to-mobile termination rates benefit mobile consumers is only necessarily true in models with at most two mobile networks, as shown in Hoernig [2014]. When the number of networks exceeds two, tariff-mediated network effects become weaker and the call externality effect becomes stronger. These two effects together imply that as the number of firms increases, higher MTRs will tend to lead to lower, instead of higher, consumer surplus.

Whether a reduction in MTRs will result in an increase or a decrease in welfare and consumer surplus on mobile networks *considered in isolation* is thus ambiguous, and depends upon the strength of call externalities and the number of competing firms in the industry. In our simulations we find that welfare increases in both the mobile and fixed markets when MTRs are reduced, and consumer surplus in the mobile market increases for reasonable values of the call externality parameter. Hence the trade-off between increasing welfare and maintaining consumer surplus in the mobile market disappears once these factors are taken into account.

Our model thus provides a rigorous, quantifiable approach to assessing the likely conse-

[9] See Armstrong and Wright [2009a]. Genakos and Valletti [2011] present some empirical evidence on the strength of this effect in twenty countries.

[10] Indeed, the Royal Economic Society's media briefing ("European Decision on Mobile Charges May Not Benefit Customers") emphasized 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*".

quences of changes in policy towards regulating MTRs, in the UK and elsewhere. Another natural application is to analyze the recent merger between Orange and T-Mobile, which has created a single firm with about 40% of all UK mobile subscribers. Doing so allows us to evaluate the merger's effects on economic efficiency, consumer welfare and mobile firms' profits.

We show in Section V that with MTRs set at their regulated levels for 2010/11, the overall effect of the merger depends on the strength of call externalities. For low receiver benefits the merger may be welfare-improving; when call externalities are significant, this result is reversed by the strategic incentive of the newly-merged firm to increase its off-net call prices. When call externalities are large, our simulations predict overall welfare losses from the merger exceeding £900 million per year, more than double the cost savings of £390 - £420 million per year predicted by the companies themselves. The losses in consumer surplus exceed £1.3 billion per annum for all values of the ratio of receiver/sender benefits in our simulations. Although the European Commission approved the merger, subject to certain undertakings agreed by the companies (EC [2010]), it is difficult to see how these conditions could have allayed the competition-related concerns raised by our simulations.[11]

Our modeling and simulation framework provides a parsimonious approach to translating results from economic theory into a practically relevant quantitative assessment. Naturally, this implies a trade-off. Compared with econometric methods based on data series, a calibration/simulation exercise such as the one reported in this paper cannot provide statistical error bounds or take advantage of standard model selection methods.[12] The purpose is to provide forward-looking "directional" and "order of magnitude" assessments of the likely welfare consequences of regulatory changes in MTRs, rather than possibly more precise econometric estimates which rely on historical data.[13] In order to test the robustness of our simulations, we have run the calibration and simulations for different combinations of the exogenous parameters (elasticity of mobile call demand, and strength of call externality) and for two different types of demand systems (multi-firm Hotelling and logit demands). Section 4.1 reports the results of our simulations for logit demands, and the very similar results we obtain from simulations using the Hotelling

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

[12] Hansen and Heckman [1996] describe simulation exercises of this type as "computational experiments" and provide a more general discussion of these issues.

[13] As with merger simulations, which are also of necessity forward-looking, and which have become an increasingly important instrument of competition policy since the mid-1990s. See Froeb and Werden [2000], Budzinski and Ruhmer [2010].

model are reported in Appendix C.

Section II describes the market model. Section III details our calibration to the UK market and Section IV.1 the results derived using the calibrated model. Section IV.2 discusses other issues related to reducing MTRs. Section V reports on the effects of the Orange/T-Mobile merger, and Section VI concludes. Appendix A provides a brief overview of the UK telecoms market in 2010/11.

II A MODEL OF THE UK COMMUNICATIONS MARKET

Our model of the UK mobile communications market is a generalization of the network competition models of Laffont *et al.* [1998] and Carter and Wright [1999, 2003] to include many asymmetric networks and calls to and from a fixed network, as in Hoernig [2014].[14] We extend the latter model by allowing for a generic system of subscription demands, explicitly including a fixed network, and by determining the market equilibrium following the merger of two networks which retain their separate "brands", or identities, as described below in Section II.3.[15]

In the UK voice telephony market, as all over the EU, the only prices that are subject to regulation are the termination rates on mobile and fixed networks. All relevant retail prices on fixed and mobile networks are unregulated. This applies in particular to the price of fixed-to-mobile calls.

II.1 *Model Setup*

Networks: We assume $n \geq 2$ mobile networks of different sizes and one fixed network.[16] We consider imperfect competition in the mobile market, with consumers perceiving mobile networks as providing substitutable, horizontally differentiated services, as described

[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 [2014] 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, which significantly reduces the complexity of the modeling. Even so, no closed-form solution for the equilibrium is derived.

[15] This is the relevant case as Orange and T-Mobile have maintained their individual brands following their merger, but share their networks and costs. See Ofcom [2010a, p. 320] and the Everything Everywhere Ltd website (everythingeverywhere.com).

[16] 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 for simplicity.

below. Consumers perceive fixed and mobile networks as providing non-substitutable services, however, so there is no strategic competition between fixed and mobile networks.

Each mobile network's subscriber market share is denoted by $\alpha_i > 0$, $i = 1, ..., n$, with $\sum_{i=1}^{n} \alpha_i = 1$. We assume that the vector of market shares $\alpha = (\alpha_i)_{n\times 1}$ can be written as

$$\alpha = g\left(\sigma\left(A + w\right)\right), \tag{1}$$

where $\sigma > 0$ is the degree of product differentiation (lower σ indicates more differentiation), and $A = (A_i)_{n\times 1}$ and $w = (w_i)_{n\times 1}$ are the vectors of network-specific connection surplus and call surplus to be defined below, respectively. The function $g : \mathbb{R}^n \to [0,1]^n$ is assumed to be differentiable with symmetric Jacobian G. This modeling framework incorporates for example the multi-firm Hotelling model of Hoernig [2014], $\alpha = \alpha_0 + \sigma B\left(A + w\right)$, where $\alpha_0 = (\alpha_{0i})_{n\times 1}$ and $B = (B_{ij})_{n\times n}$ are constants, or the logit model $\alpha_i = e^{\sigma(A_i + w_i)} / \sum_{j=1}^{n} e^{\sigma(A_j + w_j)}$ as in Calzada and Valletti [2008]. We have calibrated the model for both, but due to limitations of space we only report the results for the latter in the main text.

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. Mobile network i incurs a yearly fixed cost per customer of f_i, and has on-net costs of $c_{ii} = c_{oi} + c_{ti}$ per call minute, where the indices o and t stand for origination and termination, respectively. The regulated mobile termination rate (MTR) on network i is denoted a_i, so the per-minute 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 regulated termination rate is a_f and c_{tf} is the cost of call termination on the fixed network. Hence the cost of a call from mobile network i to the fixed network is $c_{if} = c_{oi} + a_f$. The average cost of a call from the fixed to the mobile networks is $c_{fm} = c_{of} + \bar{a}$, where $\bar{a} = \sum_{i=1}^{n} \alpha_i a_i$ is the market-share weighted average MTR. On the fixed network, we only consider calls between the fixed and mobile networks and neglect other services, including on-net fixed 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,[17] 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, i.e. $p_{ij} = p_{ik}$ for all $j, k \neq i$. The price

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

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.[18] The fixed network charges a per-minute price p_{fm}. In order to determine the equilibrium in the mobile market in this section we do not need to make assumptions about how it is determined.

Consumer Surplus We assume a fixed mass M of subscribers in the mobile market, and mass N of 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. The demand for calls differs between subscribers on mobile networks and on the fixed network, however.

Subscribers receive a fixed utility A_i from being connected to network i; utility from making calls, as a function of call length and the number of calls made; and 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 $0 \leq \beta \leq 1$ 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 $v(p) = u(q(p)) - pq(p)$ and $q(p) = -v'(p)$. In the following we will simplify notation by denoting $q_{ii} = q(p_{ii})$, $u_{ij} = u(q_{ij})$, $v_{ij} = v(p_{ij})$ etc.

A single consumer's surplus from a given tariff is the sum of the net utility from making and receiving calls minus the subscription fee. Consumers make their choice of network based the net surplus resulting from their own personal preferences for specific networks and the tariffs on offer. A client of network i obtains the following surplus, before taking network preferences into account:

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

where $h_{ij} = (v_{ij} + \beta u_{ji})$ and $h_{if} = (v_{if} + \beta u_{fi})$. In matrix notation, this can be written as

$$w = Mh\alpha + Nh_f - F, \tag{2}$$

where we have introduced the matrix $h = (h_{ij})_{n \times n}$ and the vectors $h_f = (h_{if})_{n \times 1}$ and $F = (F_i)_{n \times 1}$.

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

Aggregate consumer surplus in the mobile market is given by $S = M\alpha'(A + w)$ minus transport cost in the Hotelling model, and $S = \frac{M}{\sigma}\ln\left(\sum_{i=1}^{n} e^{\sigma(A_i+w_i)}\right)$ in the logit model. Consumer surplus in the fixed telephony market from fixed-to-mobile and mobile-to-fixed calls is

$$S^f = NM\sum_{i=1}^{n}\alpha_i(v_{fi} + \beta u_{if}).$$

Profits and welfare: Network i's profits are given by the sum of profits from subscriptions, outgoing and incoming calls:

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

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 and from other mobile networks. Furthermore, $Q_i = (p_{if} - c_{if})q_{if} + (a_i - c_{ti})q_{fi}$ are the profits from mobile-to-fixed calls and fixed-to-mobile termination. Joint profits of all mobile networks can be written as

$$\Pi = M\alpha'(MR\alpha + NQ + F - f),$$

where $R = (R_{ij})_{n\times n}$, $Q = (Q_i)_{n\times 1}$ and $f = (f_i)_{n\times 1}$.

The profits of the fixed network from fixed-to-mobile calls are

$$\pi^f = NM\sum_{i=1}^{n}\alpha_i(p_{fm} - c_{fo} - a_i)q_{fm} = NM(p_{fm} - c_{fo} - \bar{a})q_{fm}.$$

Total welfare is the sum of consumer surplus and profits,

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

II.2 *Pre-Merger Equilibrium*

We model the imperfectly competitive market outcomes as Nash equilibria in multi-part tariffs, i.e. the outcomes that result from mobile networks offering tariffs such that no single network would like to change its offer given the other offers. These equilibrium outcomes determine call prices, subscription fees, the resulting consumer surplus and network profits. In the following we will the state equilibrium prices and fixed fees. The corresponding derivations for the pre- and post-merger cases can be found in Appendix B.

In the pre-merger equilibrium, firms charge the following call prices:

$$p_{ii} = \frac{c_{ii}}{1+\beta}, \; p_{if} = c_{if}, \;\; p_{ij} = \frac{\sum_{l \neq i} \alpha_l c_{il}}{1-(1+\beta)\alpha_i}, \; j \neq i. \tag{3}$$

That is, as usual with multi-part tariffs, on-net prices are set at the efficient level in order to maximize surplus. They are set below cost in order to internalize the call externality. Mobile-to-fixed prices are set at their respective cost (the call externality of receivers on the fixed network is not internalized by mobile networks). On the other hand, off-net prices are set on the basis of perceived off-net cost, which include the benefits of receiving calls by customers of rival networks. As a result, off-net prices increase with network size and the strength of the call externality, as in Jeon et al. [2004] in a duopoly model.

Firm i's equilibrium fixed fee is

$$F_i = f_i - NQ_i + M \sum_{j=1}^{n} \alpha_j \left(\hat{R}_{ij} - R_{ij} \right), \tag{4}$$

where

$$\hat{R}_{ii} = \frac{1}{\sigma M H_{ii}} - \sum_{j=1}^{n} \frac{H_{ji}}{H_{ii}} R_{ij}, \;\; \hat{R}_{ij} = 0 \; \forall \; j \neq i$$

and $H_{ji} = -\left(d\alpha_j / dF_i \right) / \sigma$, for all $j, i = 1, ..., n$, as derived in Appendix B.

Fixed fees thus consist of fixed costs and a fixed-to-mobile waterbed effect NQ_i, apart from a term that depends on the differentiation σ and the strength of network effects in the mobile market. With $\hat{R} = (\hat{R}_{ij})_{n \times n}$, the equilibrium fixed fees can be written as

$$F = f - NQ + M(\hat{R} - R)\alpha,$$

which, after substitution into (2) and (1), finally gives rise to the equilibrium condition on market shares

$$\alpha = g \left(\sigma \left[A - f + M(h + R - \hat{R})\alpha + N \left(h_f + Q \right) \right] \right).$$

In most cases this condition must be solved numerically, while all other variables can then be computed explicitly.

Finally, after substitution of the equilibrium fixed fees the sum of equilibrium profits in the mobile market simplifies to

$$\Pi = M^2 \alpha' \hat{R} \alpha.$$

That is, firms' profits depend on the competitiveness of the mobile market as captured in $\hat{R}$ by σ and tariff-mediated network effects as captured by h and transmitted to $H = (H_{ij})_{n \times n}$.

II.3 *Post-Merger Equilibrium*

We model the merger of two networks by assuming that their brands are kept while their pricing is determined by a unique profit-maximizing entity. This approach is realistic in our case since the merged firm kept the two brands.

After the merger, non-merged firms j maximize their profits π_j, while the firm resulting from the merger of firms i and k maximizes the sum of profits $\pi_i + \pi_k$. In equilibrium, non-merged firms continue to set equilibrium call prices as in (3). The merged firm charges the same on-net and mobile-to-fixed prices as before, but different off-net prices:

$$p_{ik} = \frac{c_{oi} + c_{tk}}{1+\beta}, \quad p_{ij} = \frac{\sum_{l \neq i,k} \alpha_l c_{il}}{1 - (1+\beta)(\alpha_i + \alpha_k)}, \ j \neq i, k.$$

Thus the merged brands charge the efficient price for calls to each other, while they set higher off-net call prices to other networks based on their joint market share (rather than individual market shares). Thus the merger amplifies strategic incentives for creating a large differential between on- and off-net prices.

As concerns fixed fees in the post-merger equilibrium, they continue to be given by expression (4). The only change is that for the merged firms i, k we now have

$$\begin{aligned} \hat{R}_{ii} &= \frac{\frac{H_{kk}}{\sigma M} - \sum_{j=1}^{n} (H_{kk} H_{ji} - H_{ki} H_{jk}) R_{ij}}{H_{ii} H_{kk} - H_{ki} H_{ik}}, \\ \hat{R}_{ik} &= -\frac{\frac{H_{ki}}{\sigma M} + \sum_{j=1}^{n} (H_{kk} H_{ji} - H_{ki} H_{jk}) R_{kj}}{H_{ii} H_{kk} - H_{ki} H_{ik}}, \end{aligned}$$

and $\hat{R}_{ij} = \hat{R}_{ji} = 0$ for all $j \neq i, k$. The fact that $\hat{R}_{ik} \neq 0$ for the merged firm translates the internalization of the competitive externality that the choice of fixed fee F_i imposes on network k. This internalization is the primary consequence of the joint setting of prices on both merged firms: Fixed fees will be set higher because there is no point in stealing either brand's clients. All further expressions for market shares and profits are as above in the pre-merger case. Note, though, that the equilibrium market shares and call prices have changed and thus also the latter fixed fees will differ from the pre-merger values. In fact, they will be higher due to the unilateral effects just mentioned.

III MODEL CALIBRATION

As we describe in detail immediately below, the key parameters of the model have been calibrated using the following information:

- Observed network costs, subscriber numbers, market shares, call quantities and total revenues, from Ofcom's *Communications Market 2011* report (Ofcom [2011b, Chapter 5]) unless indicated otherwise, where CMx indicates Ofcom's figure numbered 5.x;[19]

- the assumptions of linear call demands and logit subscription demands; the assumption of monopoly pricing of fixed-to-mobile calls;

- exogenous values for the mobile call demand elasticity ε and the call externality β, and zero exogenous fixed cost f_i.

Making an assumption about demand elasticity is necessary since we use a "snapshot" of the market at a specific moment in time. We have run our calibration and simulations for a range of values of ε and both logit and Hotelling subscription demands. Due to limitations of space, in the main text we report the outcomes for $\varepsilon = -0.5$ and logit demand only, but results in all cases are qualitatively similar.

The parameter measuring the strength of call externalities (β in our nomenclature) cannot be derived from the information provided. We report the outcomes covering the full spectrum 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.[20]

The calibration follows three successive steps, computing: 1) call demand parameters; 2) the horizontal differentiation parameter σ; and 3) the preference asymmetry parameters A. It takes explicitly into account that both Orange and T-Mobile are controlled by the same owner while remaining separate brands. Identification is cumulative over these steps, i.e. parameters computed in previous steps are used, together with additional information, to identify the parameters in the next step. All values are given in 2010 prices, as these correspond to the scaling of the available values.

Costs on mobile and fixed networks: We assume a long-run marginal or incremental cost of originating and terminating calls on mobile networks of 0.75 ppm in 2010

[19] This report contains values for 2010, the first calender year after the merger of Orange and T-Mobile, available at: http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr11/UK_all_telecoms_data.csv (consulted on March 31st, 2012).

[20] See Harbord and Pagnozzi [2010] for a discussion. As we relate below in Section V, a value above 0.5 makes simulated pre-merger market shares generally fit with observed 2009 values. While this seems a reasonable estimate, more information is needed to claim that β takes on a specific value.

prices, corresponding to Ofcom's estimate of "pure LRIC" of 0.72ppm in 2008/09 prices.[21] 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. We assume an average level for BT's regulated termination charge of 0.21 ppm,[22] and use the 2010 mobile termination rates of 4.35 ppm for Vodafone, O2, Everything Everywhere (Orange and T-Mobile), and 4.66 ppm for H3G for the calibration (4.18ppm and 4.48ppm in 2008/09 prices).

Ofcom [2007a, A19:18] indicates fixed costs per mobile subscriber of £95.38 per year. We allow for no exogenous fixed costs in our calibration since we only wish to include the avoidable per subscriber costs faced by networks, which are largely composed of handset subsidies. The value of the latter is determined by the level of 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 exogenous per-customer fixed costs are zero.[23]

Subscriber market shares: Mobile subscriptions by network operator for 2010 have been taken from CM54. These result in the subscriber market shares specified in Table I. The total number of mobile subscribers in 2010 was 81.165 million (CM16). After the merger that occurred at the beginning of 2010, Orange and T-Mobile continued to function as separate brands under its joint owner Everything Everywhere. Therefore we assume prices for both are set jointly, while consumers continue to perceive them as separate brands.[24]

[21] Prices have been adjusted to 2010 values using the RPI data available at http://www.ons.gov.uk/ons/datasets-and-tables/data-selector.html? cdid=CHAW&dataset=mm23& table-id=2.1, averaged over the corresponding calender or business (April to May) year.

[22] Ofcom [2009a], Paragraph 2.18, 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)". Our assumed average charge of 0.21 ppm is simply the midpoint between these two figures.

[23] Any truly exogenous fixed cost per customer does not affect our welfare and profit comparisons since it would cancel out when differences are taken.

[24] Mobile virtual network operators, such as Virgin Mobile and Tesco Mobile, are not included as independent firms in our analysis. Tesco Mobile is a 50/50 joint venture between Telefonica 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. See http://about.virginmobile.com/aboutus/about/history.

TABLE I
SUBSCRIBERS AND MARKET SHARES, 2010

	H3G	Vodafone	O2[25]	Orange	T-Mobile[26]
Subscribers (m)	5.55	20.08	24.28	31.20[27]	
Market Shares (%)	6.84	24.76	29.93	19.40	19.07

Utility and demand parameters: For each value of the call externality parameter β and call demand elasticity ε, we used the marginal costs and market shares reported above to compute predicted call prices from (3). We have then calibrated linear demand functions $q(p) = a - bp$ for mobile-to-mobile (MTM) calls by matching these predicted prices with the observed demand of $Q = 82,602$ million MTM call minutes per year (CM51) from $M = 81.165$ million mobile network subscribers and using the model's predictions of the relative proportions of on-net and off-net calls. For better readability these demand parameters are scaled in terms of call minutes to one million other subscribers.

Setting Q equal to total predicted MTM call minutes, we have

$$Q = M^2 \sum_{i,j=1}^{5} \alpha_i \alpha_j (a - bp_{ij}) = M^2 (a - b\tilde{p}),$$

with the average price $\tilde{p} = \sum_{i,j=1}^{5} \alpha_i \alpha_j p_{ij}$. The price elasticity of demand is

$$\varepsilon = -\frac{M^2 \tilde{p} b}{Q}.$$

Combining both expressions, we find

$$a = \frac{1}{M^2}(1 - \varepsilon) Q, \; b = -\frac{\varepsilon Q}{M^2 \tilde{p}},$$

where the latter depends on β through the average price $\tilde{p}$. Thus the demand parameters a and b are identified through the demand elasticity, the total observed call quantity, and predicted call prices (which themselves depend on observed cost, market shares and the given value of the call externality).

As mentioned above, here we report results for an elasticity of mobile call demand $\varepsilon = -0.5$. This value is consistent with estimates found in the recent literature and with those presented to the UK Competition Commission in 2003.[28] We obtain $a = 18.81$ and the following values of the demand slope depending on the strength of the call externality:

[25] Includes up to 2.5m Tesco Mobile subscribers.
[26] Includes about 4m Virgin Mobile subscribers.
[27] Ofcom only reports the joint subscriber number. We have attributed subscribers proportional to 2009 values.
[28] Dewenter and Haucap [2007] have 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

Table II
Demand Slope for MTM Calls

Parameter	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
b	1.46	1.36	1.23	1.06	0.86

The demand parameters for mobile-to-fixed calls were calibrated similarly, from the same elasticity ε, $N = 33.404$ million subscribers on the fixed network (CM1), and a total demand of 31,999 million mobile-to-fixed minutes (CM51). This results in $a_{mf} = 17.7$ and $b_{mf} = 6.15$.[29]

Subscribers on the fixed network demanded 11,852 million fixed-to-mobile (FTM) call minutes per year (CM42), with a corresponding revenue of £1,528m (CM39).[30] We assume that the fixed network sets p_{fm} to be the monopoly price over its marginal cost of $c_{fo} + \bar{a}$. This assumption is conservative for our purposes because it implies that any decrease in MTRs is passed through only partially to the FTM call price.[31] The linear demand function calibrated on FTM call minutes leads to the demand parameters $a_{fm} = 11.16$ and $b_{fm} = 0.53$. In this case the demand parameters are identified by observed prices and quantities and the assumption of monopoly pricing, i.e. no assumption about the elasticity of demand is used.

Horizontal differentiation parameter: For a given call externality β, and using the demand parameters calibrated above, we have determined the differentiation parameter σ of the logit subscription demand such that the total revenue from mobile subscriptions and metered calls is equal to £10,547m (CM47). Total revenue is given by

$$Revenue = M \sum_{i=1}^{5} \alpha_i \left(M \sum_{j=1}^{5} \alpha_j p_{ij} q_{ij} + N p_{mfi} q_{mfi} + F_i \right),$$

where the calibration uses the post-merger expressions for equilibrium fixed fees, that is, they are set jointly by Orange and T-mobile. Since revenues depend nonlinearly on σ this

-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 [2007a] 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, and used the value -0.3 (Figure A19.2).

[29] The values of the demand parameters for mobile-to-fixed calls actually have no effect at all on our results since the price and quantity of these calls remain the same in all scenarios. We present their calibration here for completeness only.

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

[31] Ofcom [2007a, A19.26] assumes that the FTM price involves a fixed retention above cost. This would imply a larger pass-through of 1 and larger increases in welfare due to lower MTRs.

condition is solved numerically. Lower (higher) σ results in higher (lower) fixed fees, and thus revenues are a decreasing function of σ. This allows us to determine the value of σ which reproduces the observed revenues.

Table III
Differentiation parameter

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
σ	0.01237	0.01202	0.01151	0.01077	0.00957
σ^{stab}	0.08769	0.06093	0.04141	0.02794	0.01788

Calibrated values for σ have always been found in the stable range, i.e. $\sigma < \sigma^{stab}$, where the latter have been determined as indicated in Hoernig [2014] and Appendix B.[32]

Asymmetry parameters: In a final step the network asymmetry parameters have been determined. Only the pairwise differences $A_i - A_j$ count and can be calibrated, therefore we normalize $A_i = 0$ for H3G. This normalization does not affect the comparison between scenarios presented below. Each A_j, $j = 1, ..., n$, then represents the additional amount per year that a subscriber would be willing to pay for switching to firm j, as compared to H3G, if call surpluses were otherwise identical.

From the logit model it follows that $\alpha_j/\alpha_i = e^{\sigma(A_j + w_j - A_i - w_i)}$, or

$$A_j = w_i - w_j + \frac{1}{\sigma} \ln \left(\frac{\alpha_j}{\alpha_i} \right),$$

which directly leads to the values in Table IV. Thus the asymmetry parameters have been identified from observed market shares, predicted equilibrium tariffs, the parameter σ, and the assumption of logit subscription demand.

Table IV
Asymmetry Parameters (£ per year relative to H3G)

Company	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Vodafone	123	122	123	126	135
O2	144	144	144	145	151
Orange	137	135	132	127	118
T-Mobile	136	134	131	126	116

With these asymmetry parameters the model replicates the 2010 (post-merger) market shares reported in Table I.

[32]This check for stability in expectations is essentially a consistency check ruling out multiple equilibria and tipping, but without further implications concerning the derivation or interpretation of our results given that it has been passed. We report it here for completeness only.

IV THE EFFECTS OF REDUCING MTRS

Section IV.1 reports our simulation results when MTRs are reduced to one of three alternatives described above. Section IV.2 considers some longer-run implications of reducing MTRs.

IV.1 *Model Results*

This section reports the results of our simulations for call externality parameter β values of 0, 0.25, 0.5, 0.75 and 1, respectively. All results are reported in £ million per calendar year in 2010 prices. Increases of the variables under consideration, as compared to the base scenario, are given by positive values and decreases by negative values.[33]

In our base scenario, mobile networks' termination rates are set at Ofcom's "LRIC+" levels for 2010. These were 4.66 ppm for H3G and 4.35 ppm for the four other mobile operators, in 2010 prices. This base scenario is compared with three other scenarios with MTRs reduced to: (i) Ofcom's current estimate of "pure LRIC"; (ii) the average price of termination on the fixed network; and (iii) zero, i.e. Bill & Keep.

As noted above, equilibrium market shares are determined endogenously in our model. Since they only change marginally compared to their original 2010 values we do not report them here.

Mobile market effects Table V reports the results of our simulations for consumer surplus, welfare and profits in the mobile market considered in isolation. As shown in the table, welfare increases in the mobile market for all values of the call externality parameter β in our simulations, and consumer surplus increases for all values of $\beta \geq 0.25$.

[33] Appendix C reports the very similar results we obtain from simulations of the Hotelling, as opposed to the logit, model.

TABLE V
CHANGES IN MOBILE MARKET WELFARE CONSTITUENTS

MTRs	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
CHANGE IN WELFARE					
Pure LRIC	296	752	1337	2170	3623
Reciprocal with Fixed	264	749	1370	2247	3747
Bill-and-Keep	246	740	1371	2261	3774
CHANGE IN CONSUMER SURPLUS					
Pure LRIC	-106	138	406	715	1078
Reciprocal with Fixed	-174	80	357	677	1050
Bill-and-Keep	-205	51	330	652	1027
CHANGE IN PROFITS					
Pure LRIC	401	614	932	1456	2544
Reciprocal with Fixed	438	670	1013	1570	2697
Bill-and-Keep	451	689	1041	1609	2748

As discussed in the Introduction, it has been argued that reducing MTRs will necessarily lead to a reduction in consumer surplus (and possibly welfare) in the mobile market, and for two reasons. First, above-cost fixed-to-mobile termination rates result in a 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 monopoly-level fixed-to-mobile termination rates. As Armstrong and Wright [2009a, p. F286] put it, "*high fixed-to-mobile termination charges are a means of transferring surplus from fixed callers to mobile recipients.*" Second, mobile subscribers can benefit from above-cost mobile-to-mobile termination rates, since these create tariff-mediated network effects which intensify competition between networks to attract subscribers (the "network competition effect"), reducing the equilibrium level of network 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]).

As already noted, these arguments are incomplete. The argument with respect to fixed-to-mobile termination rates loses much of its force when call externalities matter. To see this, observe 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 simultaneously reduces the utility received by the mobile network's subscribers by reducing q_f. With a high call externality parameter, the latter effect outweighs the former and hence welfare on mobile networks becomes a decreasing function of the level of MTRs.[34]

As demonstrated by Hoernig [2014], the argument that above-cost mobile-to-mobile termination rates benefit mobile consumers is only necessarily true in models with at most two mobile networks. It can be shown that for $n \geq 2$ symmetric networks and $j \neq i$ consumer surplus becomes, in both the Hotelling and the logit models,

$$S = \frac{n-2}{n}\left(R_{ij} + h_{ij}\right) - \frac{1}{n\left(n-1\right)}h_{ij} + const,$$

where $const$ does not depend on the off-net price. Evidently, the first term only arises with $n > 2$ networks. Hoernig [2014] then shows that consumer surplus decreases in the off-net price if

$$n > \bar{n}\left(\beta\right) = \frac{3}{2} + \frac{1}{2}\sqrt{1 + 4\frac{\beta + 1/\varepsilon}{\beta + \left(c_{ij} - c_{ii}\right)/c_{ij}}}.$$

Demand elasticities $\varepsilon < 1$ are sufficient for $\bar{n}\left(\beta\right)$ to be decreasing in the strength of call externalities, i.e. if the elasticity of call demand is low then stronger call externalities make it more likely that consumer surplus decreases with higher off-net prices. With $n > \bar{n}\left(\beta\right)$ networks, although a higher mobile-to-mobile termination rate increases the network competition effect, the loss in consumer surplus due to fewer off-net call minutes dominates.

The upshot is that it cannot be decided by pure theory 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* in markets with more than two firms.

Referring back to Table V, the lower increase in welfare when $\beta = 0$ is caused by the reduction in fixed-to-mobile transfers (the waterbed effect). With higher levels of call externalities, this effect is outweighed by the reduction in off-net call prices and the resulting increase in off-net call volumes (i.e. the "call externality effect"), induced by the lower MTRs. With very high call externalities welfare in the mobile market increases by more than £3 billion per annum.

For low values of β, consumer surplus the mobile market decreases for two reasons. Networks' profits per consumer from fixed-to-mobile transfers are reduced, and lower

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

MTRs reduce tariff-mediated network effects. Both result in higher subscription charges. For higher values of β these effects are outweighed by the call externality effect noted above, and consumer surplus increases whenever $\beta \geq 0.25$. Still, consumer surplus in the mobile market is higher under Pure LRIC than under Reciprocity or Bill & Keep.

Mobile networks' profits, on the other hand, increase for all values of β due to the network competition effect. Reduced transfers from the fixed network do not affect profits since the waterbed effect is always "full" in our model.

Fixed market effects Next, we consider the effects of reducing MTRs on the fixed market in Table VI. The model includes profits and consumer surplus from fixed-to-mobile calls, and also consumer surplus from receiving mobile-to-fixed calls. Fixed termination rates are set close to cost, so there are almost 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.

Table VI
Change Over LRIC+ Pricing

	Welfare	Consumer Surplus	Profits
Pure LRIC	714	238	476
Reciprocal with Fixed	833	278	555
Bill-and-Keep	880	293	586

Welfare in the fixed market increases significantly, for two reasons: First, transfers to mobile networks are reduced, and second, fixed-to-mobile call quantities are brought closer to their efficient levels. Due to the monopoly pricing assumption (see Section III), fixed-to-mobile calls are priced above cost, so total welfare is higher when MTRs are reduced below "pure LRIC" as this reduces the monopoly pricing distortion. It also means that the fixed network retains most of this welfare increase in the form of increased profits.

Aggregate welfare effects As shown in Table VII, total welfare, i.e. the sum of social welfare in the mobile and the fixed markets, increases significantly under all three alternative scenarios for reducing MTRs. The extent of the increase depends upon the size of the call externality parameter, and exceeds £3 billion per year when receiver benefits are large (i.e. $\beta > 0.75$).

When $\beta = 0$ (no 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. In the absence of a fixed network, LRIC-based pricing would always result in the highest welfare increase, since mobile-to-mobile calls are priced at true network cost. Since fixed-to-mobile calls are priced above cost, however, total welfare is further increased as MTRs are reduced below LRIC as this reduces the monopoly pricing distortion in fixed-to-mobile calls.

Table VII
Change in Aggregate Welfare Constituents

MTR	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Change in Aggregate Welfare					
Pure LRIC	1010	1466	2052	2885	4337
Reciprocal with Fixed	1096	1582	2202	3080	4580
Bill & Keep	1126	1620	2251	3140	4654
Change in Aggregate Consumer Surplus					
Pure LRIC	132	376	644	953	1316
Reciprocal with Fixed	103	357	635	954	1328
Bill & Keep	89	344	623	945	1320
Change in Aggregate Profits					
Pure LRIC	878	1090	1408	1932	3021
Reciprocal with Fixed	993	1225	1568	2125	3252
Bill & Keep	1037	1276	1627	2196	3334

When call externalities matter, welfare-maximizing MTRs are always below marginal cost and Bill & Keep increasingly dominates LRIC in welfare terms as we increase β from zero to one.

Aggregate consumer surplus also increases for all values of β, and when $\beta = 1$ by more than £1.3 billion in every scenario. Finally, the sum of profits in the fixed and mobile markets increases in all scenarios for any value of β.

IV.2 *Effects of Reducing MTRs: Other Issues*

Our simulations provide quantitative estimates of the likely effects of changes in MTRs, taking account of call externalities, calls to and from the fixed network, and a realistic number of firms. Our model omits certain effects, however, in assuming that the fixed and mobile markets are separate and that the total number of mobile subscribers and the structure of retail prices (i.e. "calling-party-pays") remain unchanged as MTRs are reduced. We consider these issues in this Section.

IV.2.1 Fixed-mobile substitution

Our welfare model treats fixed and mobile networks as if they operated in entirely separate markets, with no competitive interaction either at the level of calls or subscriptions. That is, we have not allowed for any substitution between fixed and mobile calls, and nor have we have considered whether changes in mobile termination rates might affect the overall numbers of subscriptions to fixed versus mobile networks.[35]

Recent reports indicate that subscriptions to fixed networks are relatively price inelastic,[36] and according to Ofcom [2009d, Fig. 4.62, p.248], more than 80% of all UK households subscribed to both fixed and mobile services in 2009.[37] Hence the assumption of no competitive interaction at the level of access or subscriptions can probably be justified.

Consumers who subscribe to both mobile and fixed networks, however, can choose between the two types of calls, depending on which is cheaper and on whether or not callers have a fixed phone available when they want to place a call. Armstrong and Wright [2009a, Section 3.3] model this form of fixed-mobile substitution by assuming that calls made to mobile networks can originate on either fixed or mobile networks, and that consumers will always choose the lower-cost form of communication. That is, they assume that fixed-to-mobile and mobile-to-mobile calls are perfect substitutes and that callers are never "on the move".

In our calibrated model, the fixed-to-mobile price is always above the highest equilibrium off-net price. Thus our results are consistent with the possibility of call substitution between fixed- and mobile-originated calls if we interpret the observed fixed-to-mobile calls as made by customers of the fixed network who do not have access to a mobile phone when they place their call. Thus explicitly modeling fixed-mobile substitution would not change our results.

IV.2.2 Market expansion

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.[38]

[35] In the next section we consider how changes in mobile termination rates might affect the numbers of subscribers to mobile networks considered in isolation.

[36] See Briglauer *et al.* [2011] and Vogelsang [2010].

[37] This figure fell to 78% in 2010 (see Ofcom [2010b, Fig. 5.67]), so a small amount of fixed-mobile substitution at this level may be taking place.

[38] Since the Competition Commission's 2003 inquiry, mobile operators in the UK have received (and paid) 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

Armstrong and Wright [2009a] have provided some theoretical support for this policy. Noting that mobile subscribers' utility increases with both the fixed-to-mobile and mobile-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 socially optimal MTRs should exceed the marginal cost of termination, and that the fixed-to-mobile and mobile-to-mobile termination rates should be set at different levels, if feasible.[39]

As discussed in Section 4.1 above, these conclusions do not necessarily survive an increase in the number of competing mobile networks and the inclusion of call externalities in the analysis. In mobile markets with more than two firms, mobile subscribers' consumer surplus is not necessarily increasing in the mobile-to-mobile termination rate. Indeed, our results show that if a realistic number of networks is taken into account, then mobile consumer surplus may actually be *decreasing* in the termination rate, in particular if call externalities are significant.

Furthermore, when call externalities matter, a high fixed-to-mobile termination rate does not necessarily increase the surplus of mobile subscribers via the "waterbed effect" since fewer fixed-to-mobile call minutes will the received by mobile customers. Whether fixed-to-mobile termination rates can be used to increase mobile take-up is therefore a question that needs to be answered case-by-case. Its answer depends upon the strength of call externalities and other market parameters, such as the elasticity of demand for fixed-to-mobile calls.

Further doubt is cast on the market expansion argument by evidence on mobile subscription or penetration rates in Bill & 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

[2009, Section 4]). Network externality surcharges have also been applied in Belgium, Greece, Italy and Sweden (Cullen International [2008]), although the European Commission (EC [2009b]) now recommends against this policy.

[39] 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.

for multiple subscriptions, which are more common in CPNP countries, there is little measurable difference in penetration rates between Bill & 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 & Keep countries, mobile subscription levels do not appear to depend on the level of MTRs in mature markets.[40]

It is therefore unclear whether reducing either fixed-to-mobile or mobile-to-mobile termination rates will result in a decrease or increase in the overall number of mobile subscribers, and our results reflect this ambiguity. When call externalities are neglected, lower MTRs may reduce consumer surplus in the mobile market which could result in a long-run reduction in the number of mobile subscribers. If call externalities matter, on the other hand, then lower MTRs increase mobile-market consumer surplus, and this should lead to market expansion. By holding the number of mobile subscribers fixed, our model is conservative in the sense that it then likely underestimates (in Table V) either the decrease or increase in consumer surplus associated with lower termination rates.

V THE ORANGE/T-MOBILE MERGER

Another application of our model is to analyze the merger between Orange and T-Mobile in the UK mobile market, approved by the European Commission in 2010. The two operators merged in May 2010 to form a new company called Everything Everywhere Ltd., which, based on values at the end of 2009, had a combined market share of more than 40% of UK mobile subscribers (a total of 34.1 million, including MVNOs such as Virgin Mobile). Our simulation model allows us to estimate the merger's unilateral effects on economic efficiency, consumer welfare and mobile firms' profits.

The computational simulation of welfare effects of real-world (proposed) horizontal mergers in oligopolistic markets has become an increasingly important instrument of competition policy since the mid-1990s, both in the U.S. and in the EU. Merger simulation models have been employed by antitrust authorities, merging companies and courts to assess the pro- or anticompetitive effects of proposed mergers. Like other merger simulations, we use a standard oligopoly model calibrated to observed prices and quantities to predict the effects of the Orange/T-Mobile merger on the prices and quantities of the merging firms and their rivals (see Froeb and Werden [2000], Budzinski [2009], Budzinski and Ruhmer [2010]). Contrary to these papers, however, we have based our calibration on post-merger outcomes, and simulate what the market would have looked like in 2010

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

if the merger had not occurred.

As described in detail in Section II, we capture the effects of the merger by assuming that Orange and T-Mobile maintain their separate identities, or "brands", but jointly decide on their profit-maximizing call prices and subscription charges.[41] This means that the number of brands and the consumer preference space remain unchanged before and after the merger. Thus welfare and market outcomes pre- and post-merger can be consistently compared independently of assumptions about the functional form of demand.

We analyze the merger under different assumptions concerning the level of MTRs. First, mobile networks' MTRs are set equal to the 2010 values set by Ofcom, i.e. those that have been used in the model calibration. Second, we simulate the hypothetical effects of the merger assuming that MTRs had been reduced zero (i.e. Bill & Keep) already before to the merger. All reported results are stated in £ million per calendar year in 2010/11 prices.[42]

Effects of the Merger under 2010/11 MTRs We first consider the changes in mobile firms' market shares caused by the merger. In Table VIII we report observed market shares from the last pre-merger year 2009, and for the first post-merger year 2010, with simulated pre-merger market shares for 2010 values under different assumptions concerning the strength of call externalities.

For all values of the call externality parameter the merger leads to a reduction in the merging firms' market shares, since these firms raise their prices and lose some subscribers. Comparing simulated 2010 pre-merger market shares to those observed in 2009, the former match the latter more closely for values of $\beta > 0.5$. This result may be seen as providing a rough indication of the relevant range of values for the call externality parameter.

[41] This is the relevant case, since the companies had announced that the T-Mobile and Orange brands would continue to operate in the UK for at least 18 months following the merger (see Ofcom [2010a, p. 320]).

[42] Increases of the variables under consideration are given by positive values and decreases by negative values. The point of comparison in all cases is the pre-merger outcome under either level of MTRs (2010 values or Bill & Keep). Consumers on the fixed network and the fixed network itself are not affected by the merger, given that MTRs are held fixed. Thus all effects are located in the mobile market.

Table VIII
Pre- and Post-merger Market Shares

	Post-merger	Pre-merger, simulated for 2010					Pre-merger
	2010	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$	2009
H3G	6.8	5.57	5.72	6.00	6.49	7.42	6.1
Vodafone	24.8	20.96	21.1	21.5	22.35	23.99	23.46
O2	29.9	25.76	25.79	26.00	26.49	27.41	27.92
Orange	19.4	23.98	23.82	23.38	22.47	20.72	21.04
T-Mobile	19.1	23.74	23.57	23.12	22.20	20.46	21.41

With MTRs set at their regulated levels for 2010/11, the welfare effects of the merger depend on the strength of call externalities (see Table IX). In the absence of call externalities ($\beta = 0$), the merger reduces welfare least, as a result of a number of competing effects. First, by moving more subscribers on to the largest network, the merger improves welfare by reducing the allocative inefficiency associated with high off-net call prices. That is, subscribers on the merged network benefit from being able to make more efficiently-priced on-net calls. This observation provides a stark illustration of the inefficiencies created by the LRIC+ approach to regulating MTRs. In the absence of call externalities, efficiency 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.

Second, since the merged firms increase their fixed charges by more than other networks, equilibrium market shares increase slightly for the other firms, and decrease for the merged firm. This means that a fraction of consumers face higher calling charges for off-net calls on the smaller networks as they switch away from the merged networks. Finally, there is an additional, small welfare loss resulting from the fact that a fraction of consumers move on to their least-preferred network H3G (see the calibrated asymmetry parameters in Table IV). The overall effect is a welfare loss of £335 million per annum when $\beta = 0$.

For $\beta > 0$, however, the merged firms increase their off-net prices and aggregate welfare decreases further, with the welfare losses exceeding the cost savings of £390 - £420 million per year predicted by the companies themselves when $\beta \geq 0.5$. 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.[43]

[43] 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 Appendix D.

Table IX
Merger Effects with 2010/11 MTRs

Change in	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Welfare	-335	-396	-561	-978	-2052
Consumer Surplus	-1425	-1371	-1317	-1294	-1351
Profits	1090	975	757	316	-702

Since the merger reduces the intensity of competition between the mobile networks, it induces them to raise the level of their fixed charges, increasing profits at the expense of consumer surplus. The resulting losses in consumer surplus exceed £1.2 billion per annum for all values of β. For low values of β the reductions in consumer surplus are mirrored by increases in the mobile networks' profits, but for higher values equilibrium profits increase less, or may even decrease, since the merged networks' higher off-net prices intensify competition through tariff-mediated network effects.

Effects of the Merger with Bill & Keep If we perform our calculations with much lower MTRs, the (negative or positive) effects of the merger on welfare and efficiency are much reduced, since off-net call prices are much closer to their efficient levels. We model this by assuming that Bill & Keep is adopted prior to the merger. In this case, the merger would have reduced welfare by just £11 million per year, or may even have increased it by up to £6 million, depending on the value of β (see Table X). If we allow for the companies' claimed cost savings of £390 - £420 million per year (see Appendix D), this means that the merger would have been welfare improving for all assumed values of the call externality parameter.

But the merger would still have resulted in large decreases in consumer surplus for all values of β, exceeding £1000 million per annum for all values of β. These reductions in consumer surplus are closely mirrored by increases in networks' profits. Hence even if a regime of very low MTRs had been adopted prior to the merger, it would have created significant welfare losses for consumers and significant additional profits for mobile firms.

Table X
Merger under Bill & Keep

Change in	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Welfare	-11	-9	-5	-1	6
Consumer Surplus	-1141	-1125	-1101	-1061	-1010
Profits	1130	1117	1095	1060	1016

The European Commission 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 addressed the competition and welfare-related concerns illustrated by our simulations, however.

VI CONCLUSION

The traditional approach to regulating mobile termination rates in Europe (based on fully-allocated or "long-run incremental cost plus"), resulted in regulated MTRs an order of magnitude above reasonable estimates of long-run incremental costs on mobile networks, which in turn are much closer to marginal cost. In the presence of call externalities, efficient pricing on mobile networks requires MTRs below marginal cost. The European Commission's 2009 *Recommendation* represented 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 quantifiable approach to assessing the effects of significant reductions in MTRs in the UK mobile market, and elsewhere.

We show that reducing MTRs broadly in line with the European Commission's recommendation increases social welfare, consumer surplus and networks' profits in the UK fixed and mobile telephony markets. Depending on the strength of call externalities, social welfare may increase by as much as £1 to £4.6 billion per year. In addition, contrary to claims made in the recent literature, our results confirm that reducing MTRs can also benefit mobile subscribers considered in isolation, especially when call externalities are significant. Our welfare analysis thus lends support to a move away from fully-allocated cost pricing and towards much lower MTRs, with Bill & Keep often resulting in the largest increase in overall welfare.

We have also analyzed the likely effects of the merger between Orange and T-Mobile and shown that its overall effect on welfare depends on the strength of call externalities, with MTRs set at the their 2010 levels. A prior adoption of Bill &-Keep might have ameliorated 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 did not appear to address these concerns.

References

Analysys Mason, 2008, *Case Studies of Mobile Termination Regimes in Canada, Hong Kong, Singapore and the USA: Report for Ofcom*, 26 November, London.

Armstrong, M., 2002, 'The Theory of Access Pricing and Interconnection,' in Cave, M.; Majumdar, S. and Vogelsang, I. (eds.), *Handbook of Telecommunications Economics* (North-Holland, Amsterdam).

Armstrong, M. and Wright, J., 2007, 'Mobile Call Termination in the UK,' *MPRA Paper* Number 2344 (University Library of Munich, Germany).

Armstrong, M. and Wright, J., 2009a, 'Mobile Call Termination,' *Economic Journal*, 119, pp. F270–F307.

Armstrong, M. and Wright, J., 2009b, 'Mobile Call Termination in the UK: A Competitive Bottleneck?,' in Lyons, B. (ed.), *Cases in European Competition Policy: The Economic Analysis* (CUP, Cambridge).

Berger, U., 2004, 'Access Charges in the Presence of Call Externalities,' *B.E. Journal of Economic Analysis & Policy*, 3(1).

Berger, U., 2005, 'Bill-and-Keep vs. Cost-Based Access Pricing Revisited,' *Economics Letters*, 86(1), pp. 107-112.

Binmore, K. and Harbord, D., 2005, 'Bargaining Over Fixed-to-Mobile Termination Rates: Countervailing Buyer Power as a Constraint on Monopoly Power,' *Journal of Competition Law and Economics*, 1, pp. 49-72.

Briglauer, W.; Schwarz, A. and Zulehner, C., 2011, 'Is Fixed-Mobile Substitution Strong Enough to De-Regulate Fixed Voice Telephony? Evidence from the Austrian Markets,' *Journal of Regulatory Economics*, 39, pp. 50-67.

Budzinski, O., 2009, 'Competing Merger Simulation Models in Antitrust Cases: Can the Best Be Identified?,' *The Journal of Mergers & Acquisitions*, 6(1), pp. 24-37.

Budzinski, O. and Ruhmer, I., 2010, 'Merger Simulation in Competition Policy: A Survey,' *Journal of Competition Law & Economics*, 6(2), pp. 277-320.

Cabral, L., 2011, 'Dynamic Price Competition with Network Effects,' *Review of Economic Studies,* 78, pp. 83–111.

Calzada, J. and Valletti, T., 2008, 'Network Competition and Entry Deterrence,' *Economic Journal*, 118, pp. 1223-1244.

Carter, M. and Wright, J., 1999, 'Interconnection in Network Industries,' *Review of Industrial Organization*, 14, pp. 1-25.

Carter, M. and Wright, J., 2003, 'Asymmetric Network Interconnection,' *Review of Industrial Organization*, 22, pp. 27-46.

Competition Commission, 2003, *Vodafone, O2, Orange and T-Mobile: Reports on References Under Section 13 of Telecommunications Act 1984 on Charges Made by Vodafone, Orange, O2 and T-Mobile for Terminating Calls Made by Fixed and Mobile Networks* (HMSO, London).

Competition Commission, 2009, *Mobile Phone Wholesale Voice Termination Charges: Determination* (HMSO, London).

Competition Commission, 2012, *Reference Under Section 193 of the Communications Act 2003, Determination*, 9 February (HMSO, London).

Cullen International, 2008, *Mobile Termination Rates: Regulatory Challenges* (Belgrade).

DeGraba, P., 2003, 'Efficient Intercarrier Compensation for Competing Networks When Customers Share the Value of a Call,' *Journal of Economics and Management Strategy*, 12, pp. 207-230.

Dewenter, R. and Haucap, J., 2005, 'The Effects of Regulating Mobile Termination Rates for Asymmetric Networks,' *European Journal of Law and Economics*, 20, pp. 185-197.

Dewenter, R. and Haucap, J., 2007, 'Demand Elasticities for Mobile Telecommunications in Austria,' Ruhr Economic Papers, No. 17.

European Commission (EC), 2004, 'Guidelines on the Assessment of Horizontal Mergers under the Council Regulation on the Control of Concentrations Between Undertakings,' *Official Journal of the European Union*, 5.2.2004, pp. C31/5 - C31/18.

European Commission (EC), 2009a, *Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU*, 7 May (Brussels).

European Commission (EC), 2009b, *Explanatory Note, Commission Staff Working Document accompanying the Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU* (Brussels).

European Commission (EC), 2009c, *Implications for Industry, Competition and Consumers, Commission Staff Working Document accompanying the Commission Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU* (Brussels).

European Commission (EC), 2010, *Mergers: Commission Approves Proposed Merger Between UK Subsidiaries of France Telecom and Deutsche Telekom, Subject to Conditions* (Brussels).

ERG, 2009, *ERG Draft Common Position on Next Generation Networks Future Charging Mechanisms / Long Term Termination Issues* (European Regulators Group, Brussels).

Froeb, L. and Werden, G., 2000, 'An Introduction to the Symposium on the Use of Simulation in Applied Industrial Organization,' *International Journal of Economics and Business*, 7, pp. 133–137.

Gans, J. and King, S., 2001, 'Using 'Bill and Keep' Interconnect Arrangements to Soften Network Competition,' *Economics Letters*, 71(3), pp. 413-420.

Genakos, C. and Valletti, T., 2011, 'Testing the 'Waterbed' Effect in Mobile Telephony,' *Journal of the European Economic Association*, 9, pp. 1114-1142.

Hansen, L. and Heckman, J., 1996, 'The Empirical Foundations of Calibration,' *Journal of Economic Perspectives*, 10(1), pp. 87-104.

Harbord, D. and Pagnozzi, M., 2010, 'Network-Based Price Discrimination and 'Bill and Keep' vs. 'Cost-Based' Regulation of Mobile Termination Rates,' *Review of Network Economics,* 9(1), Article 1.

Hermalin, B. and Katz, M., 2011, 'Customer or Complementor? Intercarrier Compensation with Two-Sided Benefits,' *Journal of Economics and Management Strategy*, 20(2), pp. 379-408.

Hoernig, S., 2007, 'On-Net and Off-Net Pricing on Asymmetric Telecommunications Networks,' *Information Economics & Policy*, 19(2), pp. 171-188.

Hoernig, S., 2009, 'Market Penetration and Late Entry in Mobile Telephony', mimeo, January (Nova SBE).

Hoernig, S., 2014, 'Competition between Multiple Asymmetric Networks: Theory and Applications,' *International Journal of Industrial Organization,* 32, pp. 57-69.

Hotelling, H., 1929, ‘Stability in Competition,’ *Economic Journal*, 39, pp. 41-57.

Jeon D.; Laffont, J.-J. and Tirole, J., 2004, ‘On the Receiver Pays Principle,’ *RAND Journal of Economics*, 35, pp. 85 -110.

Laffont, J.-J.; Rey, P. and Tirole, J., 1998, ‘Network Competition: II. Price Discrimination,’ *RAND Journal of Economics*, 29(1), pp. 38-56.

Ofcom, 2007a, *Mobile Call Termination Statement*, 27 March (London).

Ofcom, 2007b, *The Communications Market 2007* (London).

Ofcom, 2008, *The Communications Market 2008* (London).

Ofcom, 2009a, *Wholesale Mobile Voice Call Termination: Preliminary Consultation on Future Regulation*, 20 May (London).

Ofcom, 2009b, *Telecommunications Market Data Tables Q1 2009* (London).

Ofcom, 2009c, *Review of BT’s Network Charge Controls*, 15 September (London).

Ofcom, 2009d, *The Communications Market 2009*, August (London).

Ofcom, 2010a, *The Communications Market 2010*, 19 August (London).

Ofcom, 2010b, *Wholesale Mobile Voice Call Termination: Market Review, Volume 2 – Main Consultation*, 1 April (London).

Ofcom, 2011a, *Wholesale Mobile Voice Call Termination: Statement*, 15 March (London).

Ofcom, 2011b, *The Communications Market 2011*, chapter 5, August (London).

Ofcom, 2011c, *Telecommunications market data tables Q3 2011*, 2 February 2012 (London).

Ofcom, 2011d, *Consultation on assessment of future mobile competition and proposals for the award of 800MHz and 2.6GHz spectrum and related issues. Annex 6: Competition Assessment,* March (London).

Orange and T-Mobile, 2009, *Combination of Orange UK & T-Mobile UK: Creating a New Mobile Champion*, 8 September.

Thompson, H.; Renard, O. and Wright, J., 2007, ‘Mobile Termination,’ in Haucap, J. and Dewenter, R. (eds.), *Access Pricing: Theory and Practice* (Elsevier, Amsterdam).

Valletti, T. and Houpis, G., 2005, 'Mobile Termination: What is the 'Right' Charge?,' *Journal of Regulatory Economics*, 28, pp. 235-258.

Vogelsang, I., 2010, 'The Relationship Between Mobile and Fixed Line Communications: A Survey,' *Information Economics and Policy*, 22 (1), pp. 4-17.

Wright, J., 2002, 'Access Pricing Under Competition: An Application to Cellular Networks,' *Journal of Industrial Economics*, 50, pp. 289-315.

Appendix A: The UK Telecoms Market

In 2010, the mobile industry in the UK had around 81 million subscribers and consisted of four networks, Vodafone, O2, Everything Everywhere (EE - the recently merged Orange and T-Mobile) and the smaller 3G network, Hutchison 3G (H3G). Network subscriber numbers and market shares as of the end of 2010 are shown in Table A.1 below. Orange and T-Mobile merged their networks in the second quarter of 2010. Prior to the merger each company had about a 21% market share.

Table A.1
Subscribers and Market Shares, 2010

	H3G	Vodafone	O2[44]	EE[45]
Subscribers (m)	5.55	20.08	24.28	31.20
Market Shares (%)	6.84	24.76	29.93	38.47

Source: Ofcom [2011b]

Total annual retail revenue for mobile networks in 2010 was about £15 billion and mobile call termination generated revenue of approximately £2.95 billion (Ofcom [2011c]). As of 2003, Ofcom has consistently determined that the mobile retail market in the UK is effectively competitive, and since the merger of Orange and T-Mobile has found no indication that competitive pressures have significantly reduced (Ofcom [2011d]). On the other hand, as noted by Armstrong and Wright [2009a], Ofcom has equally consistently ruled that each mobile network is a monopolist with respect to call termination on its own network, given that a call to someone's mobile phone necessarily involves the call being terminated by the mobile network to which the person has subscribed.

The fixed-line sector had 33.3 million subscribers at the end of 2010, slightly less than a year previously. British Telecom's (BT's) share of fixed-line subscribers was 48.2%, followed by the cable operator Virgin Media with 14.7%, and others with 37%.[46] Annual revenues from fixed-line call and access services was about £9.2 billion. Fixed-to-mobile (FTM) calls accounted for 35% of total call revenues in 2010, while accounting for less than 10% of overall fixed call minutes. BT's margin, or "retention" on FTM calls, i.e. the difference between its FTM retail price and the mobile termination charge, was subject to regulation in 1999, but has been unregulated since 2003.

Mobile Call Termination Regulation

[44] Includes about 2m Tesco Mobile subscribers.
[45] Includes about 4.5m Virgin Mobile subscribers.
[46] The majority of these are "indirect access" providers which use BT's fixed line network to offer services via wholesale line rental and local loop unbundling.

The regulation of mobile termination rates in the UK has generated huge amounts of regulatory controversy, and been the subject of five Competition Commission enquiries and numerous court cases since its inception in 1998. In that year the then UK telecommunications regulator, Oftel, proposed reductions in the fixed-to-mobile termination rates of the two largest mobile networks, BT's Cellnet (the precursor to the current O2) and Vodafone. These reductions were challenged by the mobile companies (with BT's support), leading to an enquiry by the Monopolies and Mergers Commission, the precursor of the current Competition Commission.[47] The MMC concluded that Cellnet's and Vodafone's FTM termination rates were too high in relation to overall costs, and they were subsequently regulated with a price cap, reducing these charges in 1999 by approximately 33% to 11.7 ppm.

The expiry of this price cap in March 2002 led to an enquiry by the Competition Commission (see Competition Commission [2003]) which upheld Oftel's new price cap covering all four mobile networks and both FTM and mobile-to-mobile (MTM) termination charges. Shortly before the 2002 enquiry, a fifth network, H3G, had entered the market, although this incipient network was excluded from the investigation. Subsequent decisions by Ofcom (the current UK telecommunications regulator) in 2004 and 2007 extended these regulations, progressively reducing both FTM and MTM termination rates, and by 2007 subjecting all five networks (including H3G) to MTR price cap regulation.

Table A.2 shows the history of average mobile termination charges from 2001 to 2006 for all UK networks: termination charges approximately halved over this period due to tightened regulation.

Table A.2
Average Mobile Termination Charges to 2006

	2001	2002	2003	2004	2005	2006
All UK Networks (ppm, nominal)	11.1	10.7	9.9	7.9	5.9	5.5

Source: Ofcom [2007b, Figure 4.40]

Table A.3 shows the regulated MTRs of the five mobile networks from 2007/08-2010/11. These charges reflect differences in the underlying costs for different mobile technologies using different spectrum bands. As a result, by 2010/11 the same charge was set for the 2G/3G companies (Vodafone, O2, T-Mobile and Orange), based on the average costs of a hypothetical efficient operator. H3G continued to receive a higher charge, recognizing the higher fixed costs it faced as a 3G-only entrant (Ofcom [2011a, para 2.15]).

[47]The enquiry did not include mobile-to-mobile termination charges, nor the FTM termination rates of the two smaller networks, Orange and T-Mobile, which had only recently entered the market.

Table A.3
Mobile Termination Charges (in 2006/07 prices)

	2007/08	2008/09	2009/10	2010/11
Vodafone & O2	5.5	5.4	4.4	4.0
T-Mobile & Orange	6.0	5.7	4.5	4.0
H3G	8.9	7.5	5.5	4.3

Source: Ofcom [2011a, Table 2.3]

As noted in the Introduction, until 2010/11 Ofcom regulated the mobile firms' MTRs using a fully-allocated network cost model to estimate "LRIC+". Following the European Commission's 2009 *Recommendation,* Ofcom changed its methodology with a proposal to reduce MTRs to reflect its estimates of "pure LRIC". In March 2011 Ofcom published a decision (in Ofcom [2011a]) requiring UK mobile operators to reduce MTRs from values which then exceeded 4.15 ppm to 0.72 ppm (its estimate of "pure LRIC") by 2014/15. While these reductions resulted in MTRs in the UK that remain an order of magnitude above those in the United States, they nevertheless represent a dramatic reversal in regulatory policy. Table A.4 shows the resulting price caps from 2010/11 to 2014/15. It also shows the recalculated charges and faster glide path proposed by the Competition Commission in February 2012, following appeals of Ofcom's new pure LRIC-based charges by all four mobile networks and BT.

Table A.4
Mobile Termination Charges (in 2008/09 prices)

	2010/11	2011/12	2012/13	2013/14	2014/15
Ofcom 2011	4.18 (4.48)	2.69	1.74	1.12	0.72
CC 2012	4.18 (4.48)	2.29	1.25	0.67	0.65

Source: CC [2012] (charges in parentheses for 2010/11 refer to H3G)

As noted above, since 2002 the price caps for FTM and MTM termination rates have been set equal to each other, although there has been no regulatory constraint preventing the networks from setting different MTM and FTM termination charges. The actual FTM and MTM termination charges set by networks have always been equal to the maximum allowed charge, however.[48]

Prices and Call Volumes

Table A.5 below shows the average pence per-minute retail prices for on-net and off-net MTM calls, as well as mobile-to-fixed calls, from 2005 (see Armstrong and Wright [2009a] and Harbord and Pagnozzi [2010] for further discussions of the evidence on this

[48] Armstrong and Wright [2009a] provide theoretical arguments both for why and why not mobile networks should want to set MTM charges lower than FTM charges, absent any regulatory constraints.

score). For 2007-2008, Ofcom did not report separate figures for off-net versus on-net call revenues and volumes, hence these figures are absent.[49]

The decline in off-net MTM retail call prices over the period is no doubt partly, or largely, due to the reductions in termination charges documented in Tables A.1 to A.4 above. Despite the narrowing of the differentials between off-net and on-net calls prices, the differences remain significant in percentage terms. Note that average on-net call prices have been consistently much lower than the corresponding MTRs, illustrating the oft-observed fact that mobile networks do not treat regulatory estimates of "LRIC+"as costs that need to be recovered from calls made on their own networks. In the absence of call externalities, theory predicts that the on-net/off-net price differential will be equal to 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 the information provided by Ofcom.[50]

Table A.5
Average price of mobile calls (ppm)

	2005	2006	2009	2010	2011 (3rd quarter)
Mobile to fixed calls			2.2	2.0	1.8
On-net MTM calls	4.1	3.5	1.5	1.4	1.3
Off-net MTM calls	11.2	8.9	3.8	3.2	2.6
Price differential, off-net minus on-net	7.1	5.4	2.3	1.7	1.3
Percent price differential, off-net/on-net	63.4%	60.7%	60.3%	57.7%	50.3%

Source: Authors' calculations from Ofcom [2007b, 2011c]

Table A.6 shows that the relative volumes of off-net and on-net calls have been consistently unbalanced. On-net calls have consistently accounted for more than 30% of all mobile-originated call minutes, while off-net call volumes have typically been only slightly below or above 30%. As noted by Armstrong and Wright [2009a, p. F275], with equal off-net and on-net charges and four roughly symmetric networks (i.e. prior to the merger of Orange and T-Mobile), we would expect off-net traffic to be approximately three times greater than on-net traffic, rather than the much lower volumes of off-net traffic observed.

[49] It 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. The on-net and off-net average prices in Table 2.5 ignore subscription or "access" charges, which typically include a number of "free" minutes for all call types. Hence the absolute levels of these charges is probably underestimated in Table 2.5, since it has implicitly been assumed that the marginal price of a "within bundle" call is zero.

[50] See Harbord and Pagnozzi [2010] for further discussion of this point.

The high prices for off-net calls relative to on-net calls shown in Table A.5 is likely responsible for much of this imbalance in calling patterns.[51]

Table A.6
Shares of types of mobile call minutes

	2007	2008	2009	2010	2011 (3rd quarter)
Mobile to fixed calls	27.93%	25.52%	26.21%	25.61%	25.41%
On-net MTM calls	32.03%	34.45%	34.75%	35.64%	32.73%
Off-net MTM calls	27.43%	27.14%	31.51%	30.47%	33.81%
Ratio: On-net/off-net	1.17	1.27	1.10	1.17	0.97

Source: Authors' calculations from Ofcom [2008, 2011c]

As found by our welfare analysis in Section IV.1, a major benefit of reducing MTRs is to reduce (or eliminate) the allocative inefficiency caused by off-net charges which significantly exceed marginal costs, and which constitute a barrier to calling subscribers on other networks.

Finally, Table A.7 compares average FTM call prices to average fixed-to-fixed (FTF) call prices since 2005.

Table A.7
Average prices of fixed-to-mobile calls (ppm)

	2005	2006	2007	2008	2009	2010
FTM calls	11.49	10.98	11.55	12.51	13.26	13.35
FTF calls	1.51	1.48	1.51	1.49	1.54	1.55
Price differential, FTM-FTF	9.98	9.50	10.04	11.02	11.72	11.80

Source: Authors' calculations from Ofcom [2008, 2011c]

Observe that the average price differential exceeds the FTM termination rate in every year, and by increasing amounts. Indeed, the price differential has been increasing slowly as MTRs have been reduced, with only very small changes in the price of FTF calls. This has led to complaints by the mobile firms that reductions in the FTM termination charge do not benefit consumers, but merely transfer profits from mobile companies to fixed-line operators (see Competition Commission [2012, Section 2]). The lack of responsiveness of FTM prices to reductions in MTRs is difficult to explain, even if one assumes (as we do in our simulations reported in Section IV.1) that there is a single monopoly fixed-line operator.

[51] 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.

Appendix B Equilibrium Pre- and Post-Merger Outcomes

Call prices: In order to determine call prices, we follow the standard technique of finding the optimal pricing structure while holding market shares constant through an appropriate adjustment of the fixed fee F_i. The equilibrium fixed fees will then be determined in a second step. This procedure is correct in our general setting since off-net call prices are uniform and subscription demand is inelastic (Hoernig [2014] shows that this is no longer true for non-uniform off-net calls or elastic subscription demand). In all of the following, we assume that the relevant necessary second-order conditions hold.

For on-net prices p_{ii} and the mobile-to-fixed price p_{if} firm i holds $w_i = M\sum_{k=1}^{n}\alpha_k h_{ik} + Nh_{if} - F_i$ constant, or, using $dv/dp = -q$ and $du_{ii}/dp_{ii} = p_{ii}q'_{ii}$,

$$\begin{aligned}
0 &= M\alpha_i \frac{dh_{ii}}{dp_{ii}}dp_{ii} - dF_i \Leftrightarrow \frac{dF_i}{dp_{ii}} = M\alpha_i\left(\beta p_{ii}q'_{ii} - q_{ii}\right),\\
0 &= N\frac{dh_{if}}{dp_{if}}dp_{if} - dF_i \Leftrightarrow \frac{dF_i}{dp_{if}} = -Nq_{if}.
\end{aligned}$$

On the other hand, due to the call externality a change in p_{ij} not only affects w_i but also $w_j = M\sum_{k=1}^{n}\alpha_k h_{jk} + Nh_{jf} - F_j$, with

$$dw_i = -M\left(1-\alpha_i\right)q_{ij}dp_{ij} - dF_i,\ dw_j = M\alpha_i\beta p_{ij}q'_{ij}dp_{ij}.$$

Note that under uniform off-net prices $dw_j = dw_k$ for all $j, k \neq i$. Let E be the $(n \times 1)$-vector of ones. From $\sum_{j=1}^{n}\alpha_j = E'\alpha = 1$ it follows that $E'G = 0$, and by symmetry of G also that $GE = 0$. The effect of a small change in surplus dw on market shares is $d\alpha = \sigma G dw$. Thus market shares do not change if dw is proportional to E, i.e. if $dw_i = dw_j$ for all j, or

$$\frac{dF_i}{dp_{ij}} = -M\left[\left(1-\alpha_i\right)q_{ij} + \alpha_i\beta p_{ij}q'_{ij}\right].$$

Thus firm i's first-order conditions on profit-maximization become ($\bar{c}_{ij} = \sum_{l\neq i}\alpha_l c_{il}/\left(1-\alpha_i\right)$ is the average off-net cost)

$$\begin{aligned}
0 &= \frac{d\pi_i}{dp_{ii}} = M^2\alpha_i^2\left(q_{ii} + (p_{ii}-c_{ii})q'_{ii} + \beta p_{ii}q'_{ii} - q_{ii}\right),\\
0 &= \frac{d\pi_i}{dp_{ij}} = M^2\alpha_i\left(1-\alpha_i\right)\left(q_{ij} + (p_{ij}-\bar{c}_{ij})q'_{ij} - q_{ij} - \frac{\alpha_i}{1-\alpha_i}\beta p_{ij}q'_{ij}\right),\\
0 &= \frac{d\pi_i}{dp_{if}} = MN\alpha_i\left(q_{if} + (p_{if}-c_{if})q'_{if} - q_{if}\right).
\end{aligned}$$

The resulting call prices are

$$p_{ii} = \frac{c_{ii}}{1+\beta},\ p_{if} = c_{if},\ p_{ij} = \frac{\sum_{l\neq i}\alpha_l c_{il}}{1-(1+\beta)\alpha_i},\ j \neq i.$$

These three types of prices represent known results for multi-part tariffs in the presence of call externalities in duopoly models: 1) the on-net price is set at the efficient level that internalizes the call externality; 2) the mobile-to-fixed price is set at cost, since the call externality on fixed consumers is not internalized by mobile networks; and 3) the off-net price is strategically distorted upwards in the presence of the call externality.

The two merged firms (let us call them 1 and 2, and the merged network have market share $\alpha_{1+2} = \alpha_1 + \alpha_2$), when maximizing joint profits $\pi_1 + \pi_2$, will set the on-net prices p_{ii} and mobile-to-fixed price p_{if} as above, thus we only have to determine the prices p_{12}, p_{21} and off-net prices p_{ij} ($j \geq 3$). While it seems intuitive that calls between the two merged networks should be priced at on-net level, and off-net prices based on the joint market share, we will present the corresponding derivations because they involve simultaneous changes in both fixed fees. The merged network chooses its prices p_{12} and p_{1j} while adjusting F_1 and F_2 as to keep market shares constant (the determination of p_{21} and p_{2j} follows the same logic). Thus for calls from network 1 to network 2, the adjustments in fixed fees F_1 and F_2 maintain w_1 and w_2 constant, with

$$\frac{dF_1}{dp_{12}} = -M\alpha_2 q_{12},\ \frac{dF_2}{dp_{12}} = M\alpha_1\beta p_{12}q'_{12}.$$

For calls to other networks at price p_{1j}, we have, similar to the above, the surplus changes

$$\begin{aligned} dw_1 &= -M\left(1-\alpha_{1+2}\right)q_{1j}dp_{1j} - dF_1, \\ dw_2 &= -dF_2,\ dw_j = M\alpha_1\beta p_{1j}q'_{1j}dp_{1j}. \end{aligned}$$

Again, market shares do not change if $dw_1 = dw_2 = dw_j$ for all $j \neq 1, 2$, or

$$\frac{dF_1}{dp_{1j}} = -M\left(\left(1-\alpha_{1+2}\right)q_{1j} + \alpha_1\beta p_{1j}q'_{1j}\right),\ \frac{dF_2}{dp_{1j}} = -M\alpha_1\beta p_{1j}q'_{1j}.$$

That is, in both cases the adjustment in fixed fees exactly compensates for the change in surplus of subscribers on the originating and terminating network. The merged network maximizes $\pi_1 + \pi_2$, which has first-order conditions (with $\tilde{c}_{1j} = \sum_{l\neq 1,2}\alpha_l c_{1l}/(1-\alpha_{1+2})$)

$$\begin{aligned} 0 &= \frac{d\left(\pi_1+\pi_2\right)}{dp_{12}} = M^2\alpha_1\alpha_2\left[q_{12} + (p_{12}-c_{12})q'_{12} - q_{12} + (a_2 - c_{t2})q'_{12} + \beta p_{12}q'_{12}\right], \\ 0 &= \frac{d\left(\pi_1+\pi_2\right)}{dp_{1j}} = M\alpha_1\left[\left(1-\alpha_{1+2}\right)\left(q_{1j} + (p_{1j}-\tilde{c}_{1j})q'_{1j} - q_{1j}\right) - \alpha_{1+2}\beta p_{1j}q'_{1j}\right] \end{aligned}$$

The resulting profit-maximizing call prices are

$$p_{12} = \frac{c_{o1}+c_{t2}}{1+\beta},\ p_{1j} = \frac{\sum_{l\neq 1,2}\alpha_l c_{1l}}{1-\left(1+\beta\right)\alpha_{1+2}},$$

with corresponding values for p_{21} and p_{2j}. That is, as expected calls between the merged networks are priced efficiently as on-net calls, while off-net call prices are based on the merged networks' joint market share.

Subscription fees: We now determine the Nash equilibrium through networks' choice of subscription fee. From the market share equation (1) and the call surplus (2) the effect of fixed fees on market shares is determined via the implicit function theorem as

$$\frac{d\alpha}{dF} = -\sigma\left(I - \sigma MGh\right)^{-1} G \equiv -\sigma H. \tag{5}$$

A sufficient condition for $(I - \sigma MGh)^{-1}$ (and thus H) to exist is "stability in expectations", i.e. that $\sigma < \sigma^{stab}$ where σ^{stab} is the smallest value $\tilde{\sigma} > 0$ such that $\det\left(I - \tilde{\sigma} MGh\right) = 0$.[52] This is assumed in the following and has been verified in our calibrations.

As a result of the above, the effect of firm i's fixed fee F_i on firm j's market share is given by $d\alpha_j/dF_i = -\sigma H_{ji}$. A non-merging firm i maximizes π_i, with first-order condition

$$0 = \frac{d\pi_i}{dF_i} = -\sigma MH_{ii}\left(M\sum_{j=1}^{n}\alpha_j R_{ij} + Nq_i + F_i - f_i\right) + M\alpha_i\left(1 - \sigma M\sum_{j=1}^{n} H_{ji}R_{ij}\right).$$

The resulting fixed fee is

$$F_i = f_i - Nq_i + M\sum_{j=1}^{n}\alpha_j\left(\hat{R}_{ij} - R_{ij}\right),$$

where we have defined $\hat{R} = (\hat{R}_{ij})_{n\times n}$ with

$$\hat{R}_{ii} = \frac{1}{\sigma MH_{ii}} - \sum_{j=1}^{n}\frac{H_{ji}}{H_{ii}}R_{ij},\ \ \hat{R}_{ij} = 0\ \forall\ j \neq i.$$

After the merger between firms 1 and 2, the first-order conditions for the non-merging firms remain unchanged. As concerns the merged firm, its first-order conditions for maximizing $\pi_1 + \pi_2$ with respect to F_1 and F_2 can be expressed as

$$H_{11}x_1 + H_{21}x_2 = \frac{\alpha_1}{\sigma} - r_1,\ \ H_{12}x_1 + H_{22}x_2 = \frac{\alpha_2}{\sigma} - r_2,$$

where for $i = 1, 2$,

$$x_i = M\sum\nolimits_{k=1}^{n}\alpha_k R_{ik} + F_i + NQ_i - f_i,\ \ r_i = M\sum\nolimits_{k=1}^{n} H_{ki}\left(\alpha_1 R_{1k} + \alpha_2 R_{2k}\right).$$

[52] More precisely, σ^{stab} is the inverse of the largest eigenvalue in absolute terms of MGh. This is the generalization in Hoernig [2014] of the stability in expectations condition in LRT98b to the many-firm case, which rules out multiple equilibria and tipping in customer expectations.

Solving these conditions, the resulting fixed fees are again given by the above expression, where now we have

$$\begin{aligned}\hat{R}_{11} &= \frac{\frac{H_{22}}{\sigma M} - \sum_{k=1}^{n}\left(H_{22}H_{k1} - H_{21}H_{k2}\right)R_{1k}}{H_{11}H_{22} - H_{21}H_{12}}, \\ \hat{R}_{12} &= -\frac{\frac{H_{21}}{\sigma M} + \sum_{k=1}^{n}\left(H_{22}H_{k1} - H_{21}H_{k2}\right)R_{2k}}{H_{11}H_{22} - H_{21}H_{12}},\end{aligned}$$

similar for $\hat{R}_{21}$ and $\hat{R}_{22}$, and $\hat{R}_{ij} = 0$ for all $i = 1, 2$ and $j \geq 3$. For $i \geq 3$, we have $\hat{R}_{ij}$ as above for all $j = 1, ..., n$.

Appendix C Simulation Results for Hotelling Model

Table C.1

Change in Mobile Market Welfare Constituents

MTR	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Change in Mobile Market Welfare					
Pure LRIC	278	718	1284	2093	3499
Reciprocal with Fixed	243	710	1311	2164	3622
Bill-and-Keep	224	700	1310	2175	3648
Change in Mobile Market Consumer Surplus					
Pure LRIC	-10	275	587	939	1302
Reciprocal with Fixed	-59	240	566	930	1304
Bill-and-Keep	-81	220	549	916	1291
Change in Mobile Market Profits					
Pure LRIC	288	443	697	1155	2197
Reciprocal with Fixed	301	471	745	1234	2318
Bill-and-Keep	305	480	761	1259	2356

Table C.2

Change in Fixed Market Quantities

	Welfare	Consumer Surplus	Profits
Pure LRIC	714	238	476
Reciprocal with Fixed	833	278	555
Bill-and-Keep	880	293	586

Table C.3
Change in Aggregate Welfare Constituents

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Change in Aggregate Welfare					
Pure LRIC	992	1432	1998	2807	4214
Reciprocal with Fixed	1075	1543	2144	2996	4454
Bill & Keep	1104	1580	2190	3055	4527
Change in Aggregate Consumer Surplus					
Pure LRIC	228	513	825	1177	1540
Reciprocal with Fixed	219	517	843	1208	1581
Bill & Keep	212	514	843	1210	1584
Change in Aggregate Profits					
Pure LRIC	764	919	1173	1631	2673
Reciprocal with Fixed	857	1026	1300	1789	2873
Bill & Keep	892	1066	1347	1845	2943

Appendix D Efficiency Gains from the Orange/T-Mobile Merger[53]

Orange and T-Mobile forecast efficiency gains totalling £545m a year from 2015 onwards.[54] 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.

[53] We are grateful to Adam Mantzos for preparing this appendix.
[54] 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.

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, 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:

Table D.1

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