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Welfare Analysis of Regulating Mobile

David Harbord Steffen Hoernig

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

David Harbord[†]
Market Analysis Ltd

Steffen Hoernig[‡]
NOVA School of Business and Economics

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Abstract

We present a calibrated model of the UK mobile telephony market with four mobile networks; calls to and from the fixed network; network-based price discrimination; and call externalities. Our results show that reducing mobile termination rates broadly in line with the recent European Commission *Recommendation* to either "pure long-run incremental cost"; reciprocal termination charges with fixed networks; or "Bill & Keep" (i.e. zero termination rates), increases social welfare, consumer surplus and networks' profits. Depending on the strength of call externalities, social welfare may increase by as much as £990 million to £4.5 billion per year, with Bill & Keep leading to the highest increase in welfare. We also apply the model to estimate the welfare effects of the 2010 merger between Orange and T-Mobile under different scenarios concerning MTRs, and predict that consumer surplus decreases strongly.

Keywords: telecommunications, regulation, mobile termination rates, network effects, welfare, calibration

JEL Codes: D43, L13, L51, L96

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[†]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).

1 Introduction

Mobile termination rates (MTRs) are the charges that mobile firms levy on fixed networks and other mobile operators for completing, or “terminating”, calls on their networks. 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.

In contrast, in the United States and Canada, as well as in Singapore, Hong Kong and China, something close to Bill & Keep (B&K) has been adopted for mobile termination, under which MTRs are set at (or near) zero at the wholesale level.[2] In the United States mobile termination charges are set to the same rate as a local fixed-line call termination at US 0.07 cents per minute, and are reciprocal.[3] Singapore, Hong Kong and China all have adopted Bill & Keep for wholesale interconnection charging, while in Canada mobile networks pay for interconnecting traffic to and from their networks. Thus, while in the UK average mobile termination charges as of January 2011 exceeded US 6.5 cents per minute, and remained highly controversial, in so-called "Bill & Keep" countries they have been of little or no concern.

Until recently, the approach to regulating MTRs adopted by European regulatory authorities, including the telecoms regulator Ofcom in the UK, had been to allow for total

[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 these countries mobile subscribers are also often charged for receiving calls, although this is not a necessary outcome.

[3] Some mobile networks have negotiated B&K arrangements. These agreements are confidential, so the extent of their use is unknown. See OECD (2012).

cost recovery based on fully-allocated network cost models.[4] This approach has been increasingly called into question, however, by a new body of economic literature highlighting the two-sided nature of mobile interconnection markets and the significant role that call externalities play in the analysis of competition, equilibrium pricing, and entry in these markets.[5] Impetus for change also came from the entry of new mobile network operators in many European countries, which argued that their growth and profitability was being hampered by high MTRs and the significant levels of on-net/off-net price discrimination adopted by the incumbent mobile network operators.

In May 2009, the European Commission (EC, 2009a) issued a *Recommendation on the Regulatory Treatment of Fixed and Mobile Termination Rates in the EU* which embodied much of this new economic thinking, and proposed dramatic reductions in MTRs to reflect the actual incremental costs of providing voice call termination services to third parties.[6] Ofcom subsequently published a consultation document (Ofcom, 2009a) which considered the pros and cons of a number of alternative approaches to regulating MTRs discussed in the EC *Recommendation.* 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 practiced in the USA; and (iii) adopting Bill & Keep, which would effectively abolish mobile termination charges by setting them equal to zero.

While the first option is in line with the EC's Recommendation, reciprocity with fixed networks would also significantly reduce MTRs. Bill & Keep would entail the most dramatic change in policy, but variants of it have already been adopted in a number of countries, as noted above, and it was recently recommended by the European Regulators' Group (ERG, 2009). 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.[7] While these reductions will still result in MTRs in the UK an order of magnitude above those in the United States, they

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[4] This led to regulated MTRs in the UK ranging from 11.7 pence per minute (ppm) in 1999 to over 4 ppm in 2010/11, with corresponding implications for the prices of off-net calls which far exceeded the marginal costs of routing calls between networks. See Section 2

[5] 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.

[6] While not binding on member states, national regulatory authorities such as Ofcom are required to take "utmost account" of the EC recommendation. See also the accompanying documents (EC, 2009b; 2009c).

[7] Following an appeal by the companies, in February 2012 the UK´s Competition Commission recommended slightly deeper reductions to 0.65 ppm and a shorter transition period (Competition Commission 2012).

represent a significant shift in regulatory policy and a progressive convergence with B&K or near B&K countries.

The debate in the UK and Europe over the EC's *Recommendation*, while being fierce, has suffered from a lack of any serious quantitative assessment of the likely effects of the proposed reductions in MTRs on prices, welfare, and consumer and producer surplus in telecommunications markets. Both Ofcom and the European Commission discussed the pros and cons 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 capture the welfare consequences of adopting one or another of the alternatives being discussed. The principal purpose of this paper is to provide such a framework and assessment for the UK mobile market.

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.[8] Few real-world mobile markets in Europe or elsewhere satisfy either of these assumptions, however. In this paper, 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 2010) thus 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.

We calibrate this model to the UK mobile telephony 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 results in Section 5.1 show that although consumer surplus and economic welfare *may* decrease *in the mobile market considered in isolation* as we reduce the level of MTRs, aggregate welfare *and* consumer surplus increase in the telecommunications market as a whole for all reasonable values of the call externality parameter. Depending on the strength of call externalities, our model predicts market-wide welfare improvements of £900 million to £4.5 billion per annum, with Bill

[8] Armstrong and Wright (2009a) and Sauer (2011) are examples of recent papers which assume symmetric duopoly models to analyze the welfare implications of changes in MTRs. An exception to this is Hurkens and Lopez (2011).

& Keep resulting in the greatest increase in overall welfare.

A number of recent papers have argued that reducing MTRs will necessarily reduce consumer surplus, and possibly welfare, in the mobile market (Gans and King, 2001; Hoernig, 2008; Armstrong and Wright, 2009a). Indeed, the Royal Economic Society's media briefing ("European Decision on Mobile Charges May Not Benefit Customers") recently 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*". Specifically, the argument is that high *fixed-to-mobile termination charges* create profits for mobile firms, some or all of which is 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,* since these make off-net calls more expensive than on-net calls, creating network effects which favour larger networks. This intensifies competition between networks to attract subscribers, which reduces their equilibrium subscription charges. The much-cited result is that equilibrium consumer surplus on mobile networks is increasing in the level of the mobile-to-mobile termination rate (Gans and King, 2001; Armstrong and Wright, 2009a).

As we discuss in more detail in Section 5.2, however, these arguments are incomplete and do not necessarily survive the inclusion of call externalities and a more realistic number of competing networks in the analysis. The argument with respect to fixed-to-mobile termination rates loses much of its force when call externalities, or receiver benefits, matter. With a high ratio of receiver to sender benefits (i.e. the call externality parameter in our model), welfare on mobile networks becomes a decreasing function of the level of MTRs. 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, as first demonstrated by Hoernig (2010). With $n > 2$ networks, although a reduction in the mobile-to-mobile termination rate still mitigates network effects, and hence relaxes competition between mobile networks for market share, the reduction in competition may or may not be sufficient to reduce consumer surplus in equilibrium, and it is less likely to do so the more significant are call externalities.

[9] The waterbed effect refers to the phenomenon whereby a reduction (or increase) in MTRs leads to a corresponding increase (or reduction) in subscription charges to mobile subscribers. See Armstrong and Wright (2009a, pp. F284-285). Genakos and Valletti (2011) present some empirical evidence on the strength of this effect in twenty countries.

It is thus an empirical question whether a reduction in MTRs will result in an increase or a decrease in welfare and consumer surplus on mobile networks *considered in isolation.* In our simulations 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 and quantifiable approach to assessing the likely consequences of changes in policy towards regulating MTRs, in the UK and elsewhere.[10] 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 predict the merger's effects on economic efficiency, consumer welfare and mobile firms' profits.

We show in Section 6 that with MTRs set at their regulated levels for 2010/11, the overall effect of the merger depends on the strength of call externalities. For low receiver benefits the merger may be welfare-improving (if we allow for the cost savings posited by the merged firms), by moving more subscribers on to a single large network, thus avoiding the inefficiencies associated with high off-net call prices, themselves partially a product of MTRs which exceed marginal cost. In other words, the merger may help to "ameliorate" the negative effects of above-cost MTRs, allowed until recently by the UK regulatory authorities.

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.[11] Hence there is a critical level of the call externality parameter for which the merger becomes harmful to allocative efficiency and welfare. When call externalities are large, we predict that 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. With much lower MTRs, such as "pure LRIC" or Bill & Keep, the effects of the merger on aggregate welfare are much reduced, however.

Since the merger reduces the number of competitors in the mobile market, it reduces the intensity of competition between mobile networks. This induces mobile firms to raise the level of their fixed charges, increasing profits at the expense of consumer surplus.

[10]The model has also been calibrated to predict the effects of changes in regulatory policy towards MTRs in Mexico, Colombia and New Zealand.

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

The resulting losses in consumer surplus under current MTRs exceed £1.2 billion per annum for all values of the ratio of receiver/sender benefits. If MTRs were significantly reduced prior to the merger (to Bill & Keep), the consumer surplus losses are about £900 million per annum, almost all of which translates into higher profits for the mobile firms. Although the European Commission approved the merger, subject to certain undertakings agreed by the companies (see EC, 2010), it is difficult to see how these conditions could have allayed the competition-related concerns illustrated by our calibrated model.[12]

Section 2 of the paper provides a brief overview of the UK telecoms market in 2010/11. Section 3 describes the market model. Section 4 details our calibration to UK market data and Section 5.1 the results derived using the calibrated model. Section 5.2 discusses these results and considers longer-run implications of reducing MTRs. Section 6 reports on the effects of the Orange/T-Mobile merger, and Section 7 concludes.

2 The UK Telecoms Market

The mobile industry in the UK currently has around 81 million subscribers and consists 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 2.1 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 2.1 Subscribers and Market Shares, 2010

	H3G	Vodafone	O2[13]	EE[14]
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

[12] 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.

[13] Includes about 2m Tesco Mobile subscribers.

[14] Includes about 4.5m Virgin Mobile subscribers.

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%.[15] 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.

2.1 Mobile Call Termination Regulation

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 (see MMC 1999), the precursor of the current Competition Commission.[16] 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.

[15] 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.

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

Table 2.2 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 2.2. 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

The regulated termination charges in Table 2.2 include two kinds of markup over estimates of marginal or incremental termination costs. The first markup was designed to tax fixed-line callers to subsidize mobile network subscriptions in order to stimulate mobile network expansion. The second markup reflected an intended contribution to a mobile network's fixed and common costs. The first markup was referred to as the "network externality surcharge", and was introduced after the Competition Commission's 2002 enquiry (see Competition Commission 2003, pp. 225-252).[17] In its 2008/09 enquiry, following appeals of Ofcom's 2007 MTR decision by BT and H3G, the Competition Commission revisited the issue and decided that a network externality surcharge was no longer justified (see Competition Commission, 2009, Section 4).

Table 2.3 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 2011, para 2.15).

Table 2.3 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 (2011), 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

[17] 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.

reduce MTRs to reflect its estimates of "pure LRIC". Table 2.4 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 (see Competition Commission 2012), following appeals of Ofcom's new pure LRIC-based charges by all four mobile networks and BT.

Table 2.4. 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.[18]

2.2 Prices and Call Volumes

Table 2.5 below shows the average pence per-minute retail prices for on-net and off-net MTM calls, as well as mobile-to-fixed (MTF) calls, from 2005 (see Armstrong and Wright 2009a and Harbord and Pagnozzi 2010 for further discussions of the evidence on this score). From 2007-2009, Ofcom stopped reporting separate figures for off-net versus on-net call revenues and volumes, hence these figures are absent.[19]

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 2.1 to 2.4 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

[18] 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.

[19] 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.

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 Ofcom's data.[20]

Table 2.5 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) and Ofcom (2011c)

Table 2.6 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 in the data. The high prices for off-net calls relative to on-net calls shown in Table 2.5 is likely responsible for much of this imbalance in calling patterns.[21]

Table 2.6. 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) and Ofcom (2011c)

As found by our welfare analysis in Section 5.1 below, 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.

[20] See Harbord and Pagnozzi (2010) for further discussion of this point.

[21] 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.

Finally, Table 2.7 compares average FTM call prices versus average FTF call prices since 2005.

Table 2.7 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) and Ofcom (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 5.1 below) that there is a single monopoly fixed-line operator.

3 A Model of the UK Mobile 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. For more details on the theory see Hoernig (2010).[22] We extend the Hoernig (2010) model by 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 3.3.[23]

[22] 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 (2010) 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.

[23] 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).

3.1 Model Setup

Networks: We assume $n \geq 2$ mobile networks of different sizes and one fixed network.[24] 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. We consider imperfect competition in the mobile market, with consumers perceiving mobile networks as providing substitutable, horizontally differentiated services in a generalized Hotelling fashion, as described 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 $\sum_{i=1}^{n} \alpha_i = 1$. 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 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 termination rate (FTR) a_f is slightly above c_{tf}, the cost of call termination on the fixed network. Hence the cost of a call from mobile network i to the fixed network is $c_{if} = c_{oi} + a_f$. 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,[25] and per-minute call prices of p_{ii} for on-net calls and p_{ij} for off-net calls to network $j \neq i$. We assume that mobile networks charge uniform off-net prices to other mobile networks, i.e. $p_{ij} = p_{ik}$ for $j, k \neq i$. The price of calls to the fixed network is denoted p_{if}. We do not consider other services offered by mobile networks, such as international calls, SMS and data services, as their interaction with mobile voice calls is not clear and is likely to evolve over time.[26]

The fixed network charges a per-minute price p_{fm}, which we assume to be the monopoly price over a total marginal cost of $c_{fo} + \bar{a}$. This assumption is conservative for our pur-

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

[25] 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.

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

poses because it implies that only half of any decrease in MTRs is passed through to the FTM call price.[27]

Consumers: We assume a fixed number of M subscribers in the mobile market, and N subscribers on the fixed network. Each consumer makes calls to all potential recipients on the fixed and mobile networks with equal probability, so in the absence of price differentials we would have a balanced calling pattern. 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;[28] 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 $q_{ij} = q(p_{ij})$, $u_{ij} = u(q_{ij})$, $v_{ij} = v(p_{ij})$ 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

$$w = M h \alpha + N h_f - F,$$

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

[27] Ofcom (2007, 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.

[28] Only the pairwise differences $A_i - A_j$ count and can be calibrated, therefore we normalize $\min_i A_i = 0$. This normalization does not affect the comparison between scenarios presented below.

Network preferences, market shares and consumer surplus: We assume that consumers consider mobile networks as offering differentiated products in Hotelling (1929) fashion, generalized to n firms as in Hoernig (2010), and allowing for asymmetric customer valuations as in Carter and Wright (1999). Each network is located at one of n nodes, each of which is connected by a Hotelling line to all other nodes. Consumers are uniformly distributed over these $n(n-1)/2$ lines. This model of preferences was chosen so that each network competes directly with every other network for consumers (because there is a line of consumers connecting every two networks), in contrast to the well-known Salop model where each firms competes directly only with two other firms.

Assuming a line length of $2/[n(n-1)]$ and firms i and j at the endpoints, the consumer at location x_{ij} will be indifferent between networks i and j if

$$w_i + A_i - tx_{ij} = w_j + A_j - t\left(\frac{2}{n(n-1)} - x_{ij}\right),$$

where $t > 0$ indicates the strength of horizontal preferences. Thus his location is given by

$$x_{ij} = \frac{1}{n(n-1)} + \frac{1}{2t}(w_i + A_i - w_j - A_j).$$

Network i's market share is

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

where $\sigma = 1/(2t)$, and $\alpha_{0i} = 1/n + \sigma \sum_{j \neq i}(A_i - A_j)$ captures the ex-ante asymmetries due to consumers' valuations of different networks.[29] Letting $B = (b_{ij})_{n \times n}$, with $b_{ii} = n - 1$ and $b_{ij} = -1$ for $j \neq i$, we obtain

$$\alpha = \alpha_0 + \sigma Bw = \alpha_0 + \sigma B\left(Mh\alpha + Nh_f - F\right),$$

which can be rewritten as

$$\alpha = G\alpha_0 + \sigma H\left(Nh_f - F\right), \tag{1}$$

where $G = (I - \sigma MBh)^{-1}$ and $H = GB = (H_{ij})_{n \times n}$. In the presence of call externalities, this is still an implicit condition for market shares, since for $\beta > 0$ both G and H depend indirectly on α through off-net prices.

[29] Existence and stability of equilibrium require that networks be sufficiently differentiated, or that σ is not too large. See Hoernig (2010).

Letting $A = (A_i)_{n\times 1}$, aggregate consumer surplus on mobile networks, including transport cost, is given by

$$\begin{aligned} S &= M\alpha'(w + A) - M\sum_{i=1}^{n}\sum_{j\neq i}\int_0^{x_{ij}} tzdz \\ &= M\alpha'(w + A) - \frac{M}{4\sigma}\sum_{i=1}^{n}\sum_{j\neq i} x_{ij}^2. \end{aligned}$$

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

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

where $g_{fi} = v_{fi} + \beta u_{if}$ and $g_f = (g_{fi})_{n\times 1}$.

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

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

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 MTF calls and FTM 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 FTM 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 then

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

3.2 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 Annex A.

In equilibrium, firms charge the following call prices:

$$p_{ii} = \frac{c_{ii}}{1+\beta}, \; p_{if} = c_{if}, \quad p_{ij} = \frac{\sum_{l \neq i} \alpha_l c_{il}}{1-(1+\beta)\alpha_i}, \; j \neq i. \tag{2}$$

That is, as usual efficient on-net prices are set below cost in order to internalize the call externality; MTF prices are set at cost; and off-net prices are set on the basis of perceived off-net cost. These off-net prices increase with network size and the strength of the call externality.

Firm i's equilibrium fixed fee is

$$F_i = f_i - NQ_i + M \sum_{j=1}^{n} \alpha_j \left(\hat{R}_{ij} - R_{ij} \right), \tag{3}$$

where

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

Finally, 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 (1), finally gives rise to the equilibrium condition on market shares

$$[I - \sigma MB(h + R - \hat{R})]\alpha = \alpha_0 + \sigma B[N(h_f + Q) - f].$$

In the presence of call externalities the left-hand side depends on α also through h, R,and $\hat{R}$ and thus this condition must be solved numerically.

Finally, after substitution of the equilibrium fixed fees the sum of equilibrium profits in the mobile market can be written as

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

3.3 Post-Merger Equilibrium

We model the merger of two networks by assuming that their brands (or locations in consumers' preference space) are kept while their pricing is determined by a unique profit-maximizing entity. On the one hand, this approach is realistic as long as the merged firm keeps the two brands, and on the other it maintains consumers' preference space, ensuring that pre- and post-merger outcomes can be meaningfully compared.

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 (2). The merged firm charges the same on-net and MTF 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 the joint market share (rather than individual market shares).

As concerns fixed fees in the post-merger equilibrium, they continue to be given by the expression in (3) for the non-merged firms. Note, though, that the equilibrium market shares and call prices have changed and thus the latter fixed fees will differ from the pre-merger values. In fact, they will be higher due to unilateral effects. As for the merged firms i, k, we have

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

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 firms 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.

4 Model Calibration

The model described in Section 3 has been calibrated with data from Ofcom's *Communications Market 2011* report (Ofcom 2011c, Chapter 5) unless indicated otherwise, where CMx indicates Ofcom's figure numbered 5.x.[30] This report contains the data for 2010, the first calender year after the merger of Orange and T-Mobile. As we describe in detail immediately below, the model has been calibrated to observed network costs, subscriber

[30] These data are available in Excel format at: http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr11/UK_all_telecoms_data.csv (consulted on March 31st, 2012).

numbers, market shares, call quantities and total revenues. The calibration then follows several successive steps, deriving: 1) demand parameters; 2) horizontal differentiation parameters; and finally 3) preference asymmetry parameters. It takes explicitly into account that both Orange and T-Mobile are controlled by the same owner while remaining separate brands.

The parameter measuring the strength of call externalities (β in our nomenclature) cannot be derived from the data, hence is varied between five levels, from zero (i.e. no call externalities) to the maximal value of 1 (i.e. the receiving party receives the same utility as the sending party). Arguably, a value of at least 0.5 is realistic, even if we allow for some "internalization" of call externalities between individuals in stable calling relationships with one another.[31] All other parameters have been calibrated for each specific value of the call externality β.

All values are given in 2010 prices, as these correspond to the scaling of the available data.

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 prices, corresponding to Ofcom's estimate of "pure LRIC" of 0.72ppm in 2008/09 prices.[32] 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,[33] 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 (2007, A19:18) assumes fixed costs per mobile subscriber of £95.38 per year. We allow for no exogenous fixed costs in our model since we only wish to include the avoidable per subscriber costs faced by networks, which are largely composed of handset subsidies. The value of the latter is determined by the level of fixed fees in our model,

[31] See Harbord and Pagnozzi (2010) for a discussion. As we relate below in Section 6, a value of about 0.75 makes simulated pre-merger market shares fit quite well with observed 2009 values. While this seems a reasonable estimate, more evidence is needed to claim that β takes on a specific value.

[32] 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.

[33] 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.

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.[34]

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 4.1 below. 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.

Table 4.1 Subscribers and Market Shares, 2010

	H3G	Vodafone	O2[35]	Orange	T-Mobile[36]
Subscribers (m)	5.55	20.08	24.28	31.20[37]	
Market Shares (%)	6.84	24.76	29.93	19.40	19.07

The mobile virtual network operators (MVNOs), 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.[38]

Utility and demand parameters: For each value of the call externality parameter β, we used the marginal costs and market shares reported above to compute predicted call prices from (2). 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; assumed demand elasticities; 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.

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

[35] Includes up to 2.5m Tesco Mobile subscribers.

[36] Includes about 4m Virgin Mobile subscribers.

[37] Ofcom only reports the joint subscriber number. We have attributed subscribers proportional to 2009 values.

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

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

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

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

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

Combining both expressions, we find

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

where the latter depends on β through the average price $\tilde{p}$.

We assume an elasticity of demand for mobile-originated calls of $\varepsilon = -0.5$. This value is consistent with estimates found in the recent literature and with those presented to the UK Competition Commission in 2003.[39]

We obtain $a = 18.81$ and the following values of the demand slope depending on the strength of the call externality:

Table 4.2 Demand slope for MTM calls

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
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, $N = 33.404$ million subscribers on the fixed network (CM1), and a total demand of 31,999 million MTF minutes (CM51). This results in $a_{mf} = 17.7$ and $b_{mf} = 6.15$.[40]

Subscribers on the fixed network demanded 11,852 million FTM call minutes per year (CM42), with a corresponding revenue of £1,528m (CM39).[41] Under the conservative

[39] 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 -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 (2007) 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).

[40] The values of the demand parameters for MTF 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.

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

assumption that the fixed network sets a separate profit-maximizing price for FTM calls, i.e. chooses the monopoly price given the underlying cost of origination on the fixed network and termination on mobile networks, the linear demand function calibrated on FTM call minutes leads to the demand parameters $a_{fm} = 11.16$ and $b_{fm} = 0.53$.

Horizontal differentiation parameter: For a given call externality β and the resulting demand parameters, we have calibrated the differentiation parameter σ of the underlying Hotelling model 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 to determine σ. These fixed fees take into account that they are set on a joint basis for Orange and T-mobile.

Since revenues depend nonlinearly on σ this condition is solved numerically.

Table 4.3 Differentiation parameter

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
σ	0.000543	0.000530	0.000510	0.000480	0.000427
σ^{stab}	0.004834	0.002824	0.001834	0.001213	0.000762

Calibrated values for σ have always been found in the stable range, i.e. $\sigma < \sigma^{stab}$, where the latter has been determined as indicated in Hoernig (2010).[42]

Asymmetry parameters: Finally, given σ the network asymmetry parameters have been determined, up to an arbitrary normalization which we choose to be $\min_i A_i = 0$. That is, each A_i represents the additional amount per year that a subscriber would be willing to pay for switching to firm i, as compared to the firm with the lowest valuation, if all tariffs were identical.

Letting E be the (5×1)-vector of ones, we have $\alpha_0 = E/5 + \sigma BA$, or

$$BA = \frac{1}{\sigma}(\alpha_0 - E/5) = \frac{1}{\sigma}(\alpha - E/5) - Bw.$$

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

The only unknown at this stage is A, but it cannot be determined directly because B has less than full rank. Letting $A = \tilde{A} - E\tilde{a}_0$ where $E'\tilde{A} = 0$ and $\tilde{a}_0 = \min \tilde{A}$, we have

$$\begin{aligned} BA &= (5I - EE')\left(\tilde{A} - E\tilde{a}_0\right) \\ &= 5E\tilde{a}_0 - 5E\tilde{a}_0 + 5\tilde{A} - EE'\tilde{A} = 5\tilde{A}. \end{aligned}$$

Thus $\tilde{A} = BA/5$, from which the asymmetry parameters A can be determined as follows:

Table 4.4 Asymmetry parameters (£ per year relative to H3G)

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Vodafone	147	147	149	153	164
O2	188	188	190	194	206
Orange	142	141	139	135	129
T-Mobile	140	139	137	133	126

With these asymmetry parameters the model replicates the 2010 (post-merger) market shares reported in Table 4.1.

5 The Effects of Reducing MTRs

Section 5.1 reports our model predictions. Section 5.2 discusses these results and considers some longer-run implications of reducing MTRs.

5.1 Model Predictions

This section reports the predictions of our calibrated model for call externality parameters β 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.

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.

Aggregate effects: As shown in Table 5.1, total welfare, i.e. the sum of social welfare in the mobile and the fixed markets, increases significantly under all three alternative scenarios for 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. $\beta > 0.75$).

Table 5.1 Change in Welfare Over "LRIC+" Pricing

	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Pure LRIC	992	1432	1998	2807	4214
Reciprocal with Fixed	1075	1543	2144	2996	4454
Bill & Keep	1104	1580	2190	3055	4527

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 MTM calls are priced at true network cost. Since FTM calls are priced above cost, however, total welfare is further increased as MTRs are reduced below "pure LRIC" since this reduces the monopoly pricing distortion in FTM calls.

When call externalities matter, welfare-maximizing MTRs are always below marginal cost for two reasons. First, in the absence of strategic effects, below-cost MTRs induce networks to "internalize" call externalities by setting off-net prices below cost. Second, since call externalities create strategic incentives for mobile firms to increase their off-net prices, reducing MTRs below marginal cost mitigates this effect, which is particularly strong on the merged networks.[43] Hence Bill & Keep increasingly dominates LRIC in welfare terms as we increase β from zero to one.

As discussed in more detail in Section 5.2, lowering MTRs reduces network effects and relaxes price competition in the mobile market. This can result in lower levels of mobile consumer surplus for small values of β. Consumer surplus in the fixed market always increases, however, due to the reduction in the FTM call price. We find that in the UK market the latter effect dominates and aggregate consumer surplus increases. For large values of β it increases by more than £1.2 billion in every scenario (see Table 5.2).

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

Table 5.2 Change in Consumer Surplus Over "LRIC+" Pricing					
	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Pure LRIC	228	513	825	1177	1540
Reciprocal with Fixed	219	517	843	1208	1581
Bill & Keep	212	514	843	1210	1584

Finally, the sum of profits in the fixed and mobile markets increases in all scenarios for any value of β (Table 5.3).

Table 5.3 Change in Profits Over "LRIC+" Pricing					
	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Pure LRIC	764	919	1173	1631	2673
Reciprocal with Fixed	857	1026	1300	1789	2873
Bill-and-Keep	892	1066	1347	1845	2943

Mobile telephony: We now consider the mobile market in isolation, that is, the effect of reducing MTRs on consumer surplus, welfare and profits in the mobile market only. As shown in Table 5.4, welfare increases in the mobile market for all values of β.

Table 5.4 Change in Mobile Welfare Over "LRIC+" Pricing					
	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Pure LRIC	278	718	1284	2093	3499
Reciprocal with Fixed	243	710	1311	2164	3622
Bill-and-Keep	224	700	1310	2175	3648

The lower increase in welfare when $\beta = 0$ is caused by the reduction in fixed-to-mobile transfers. 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 "off-net pricing 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 (see Table 5.5) decreases, and does so for two reasons. Networks' profits per consumer from FTM transfers are reduced, and lower MTRs reduce tariff-mediated network effects. Both result in higher subscription prices via the "waterbed effect" and the reduced intensity of competition between mobile firms (the "competition effect").

Table 5.5 Change in Mobile Consumer Surplus Over "LRIC+" Pricing					
	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Pure LRIC	-10	275	587	939	1302
Reciprocal with Fixed	-59	240	566	930	1304
Bill-and-Keep	-81	220	549	916	1291

For higher values of β these effects are outweighed by the off-net pricing effect noted above, and consumer surplus increases whenever $\beta \geq 0.25$. That is, the additional surplus created by the reduction in off-net call prices is at least partly retained by consumers, compensating for the countervailing negative effects.[44] 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 (see Table 5.6) due to the competition effect. Reduced FTM transfers do not affect profits since the waterbed effect is always "full" in our model.

Table 5.6 Change in Mobile Profits Over "LRIC+" Pricing					
	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Pure LRIC	288	443	697	1155	2197
Reciprocal with Fixed	301	471	745	1234	2318
Bill-and-Keep	305	480	761	1259	2356

Fixed telephony: Finally, we consider the effects of reducing MTRs on the fixed market. The model includes profits and consumer surplus from FTM calls, and also consumer surplus from receiving MTF calls. Fixed termination rates are set 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.

Welfare in the fixed market increases significantly, for two reasons: First, transfers to mobile networks are reduced, and second, FTM call quantities are brought closer to their efficient level.

Table 5.7 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

Due to the monopoly pricing assumption, the fixed network retains most of this welfare increase in the form of increased profits (see Section 3).

[44] See Section 5.2 for a more detailed discussion of these effects.

5.2 Effects of Reducing MTRs: Discussion

Our calibrated welfare model provides a rigorous and quantifiable approach to assessing 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 results show that although consumer surplus *may* decrease in the mobile market *considered in isolation* when MTRs are reduced, overall welfare, consumer surplus and firms' profits increase in the telecommunications market as a whole, for all values of the call externality parameter. Depending on the strength of call externalities, our model predicts welfare improvements of approximately £1 to £4 billion per annum, with Bill & Keep resulting in the greatest increase in overall welfare. Inclusion of the fixed-line operator and call externalities in the analysis is thus indispensable to assessing the economic effects of reductions in MTRs.

The results of our analysis qualify, or even contradict, some conclusions reached in the recent literature. We discuss these issues in Section 5.2.1 below. Our model also omits certain longer-run effects in assuming that the size of the market (i.e. 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 Section 5.2.2.

5.2.1 Short-Run Issues

Waterbed and tariff-mediated network effects: A number of recent papers have argued that reductions in MTRs will necessarily reduce consumer surplus, and possibly welfare, in the mobile market, and for two reasons. First, a fixed-to-mobile termination rate above cost results in a flow of termination profits to mobile networks, some or all of which is passed on to mobile subscribers via the "waterbed" effect. Hence mobile subscribers should prefer fixed-to-mobile termination rates set at the monopoly (i.e. profit-maximizing) level. As Armstrong and Wright (2009a, p. F286) put it, "*high FTM termination charges are a means of transferring surplus from fixed callers to mobile recipients*".

Second, mobile subscribers can also benefit from above-cost mobile-to-mobile termination rates, since these make off-net calls more expensive than on-net calls, creating network effects which favour larger networks. This intensifies competition between networks to attract subscribers, which reduces their equilibrium subscription charges. The much-cited result is that equilibrium consumer surplus on mobile networks is increasing in the level of the mobile-to-mobile termination rate (Gans and King, 2001; Armstrong and Wright, 2009a).[45]

[45] This result has led a number of authors to suggest that mobile networks should prefer to agree

While these arguments have been much aired in recent regulatory debates, they are subject to a number of important caveats. The argument with respect to fixed-to-mobile termination rates is incomplete in two important respects. First, as observed by Armstrong and Wright (2009a, p. F284), even if all fixed-line subscribers have a mobile phone, high termination rates would still create an allocative inefficiency, and hence the gain to mobile subscribers from low subscription charges is always outweighed by the welfare loss on the fixed network from high fixed-to-mobile termination rates. Since most telephone subscribers use both fixed and mobile networks, the increase in economic efficiency and welfare achieved by aligning MTRs more closely with marginal costs benefits telephony users in general.

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

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

where a is the fixed-to-mobile termination rate, c_t the marginal cost of termination, and q_f the length of the call. An increase in a above marginal cost increases the profits of the mobile network, some or all of which is passed on to mobile subscribers via the waterbed effect, but simultaneously reduces the utility received by the mobile network's subscribers from fixed-to-mobile calls through reducing q_f. With a high ratio of receiver to sender benefits (i.e. the call externality parameter in our model), the latter effect outweighs the former and hence welfare on mobile networks becomes a decreasing function of the level of MTRs.[46,47]

The argument that above-cost, mobile-to-mobile termination rates benefit mobile consumers is also incomplete. As demonstrated by Hoernig (2010), it is only necessarily true in models with at most two mobile networks. For $n \geq 2$ symmetric networks and generic $j \neq i$, consumer surplus becomes

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

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

on below-cost mobile-to-mobile termination charges, and that such an agreement would harm mobile subscribers who prefer the more intense competition created by higher MTRs.

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

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

price if

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

Demand elasticities $\varepsilon < 1$ are sufficient for $\bar{n}(\beta)$ 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 $n > \bar{n}$ networks, although a reduction in the mobile-to-mobile termination rate still mitigates network effects, and hence relaxes competition between mobile networks for market share, the loss in consumer surplus due to fewer off-net call minutes dominates.

The upshot is that it is an empirical question whether a reduction in fixed-to-mobile and mobile-to-mobile termination charges will result in an increase or a decrease in welfare and consumer surplus on mobile networks *considered in isolation*, especially in markets with more than two firms. In our calibrated results for the UK market, when call externalities are not insignificant *consumer surplus and welfare increase in both the mobile and fixed markets*. Hence, the theoretical trade-off between increasing welfare and maintaining consumer surplus in the mobile market disappears once call externalities and a realistic number of networks are taken into account.

Fixed-to-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.[48]

Recent data indicates that subscriptions to fixed networks are relatively price inelastic,[49] 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.[50] 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 FTM substitution by assuming that calls

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

[49] See Briglauer *et al.* (2011) and Vogelsang (2010).

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

made on the FTM demand curve 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 FTM and MTM calls are perfect substitutes and that callers are never "on the move".

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

5.2.2 Long-Run Effects

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.[51]

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 rates should be set at different levels, if feasible.[52]

[51] 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, 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.

[52] 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.

As discussed immediately 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 an empirical question, which depends upon the strength of call externalities and other market parameters, such as the elasticity of demand for fixed-to-mobile calls.

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 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.[53]

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 5.5) either the decrease or increase in consumer surplus associated with lower termination rates.

These models did not allow for mobile-to-mobile calls, however.

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

Receiving party pays: Finally, reducing the level of MTRs may affect the types of tariffs offered by mobile networks. In most “Bill & Keep” (or near Bill & Keep) countries (e.g. Canada, Singapore, Hong Kong, the United States), mobile firms have adopted receiving party pays (RPP), i.e. customers are "charged" for receiving calls. In many cases this simply implies that both calls made and received are bundled into a monthly "bucket" of free minutes. Cambini and Valletti (2008) and Lopez (2011) argue networks may adopt RPP when MTRs are reduced below cost.[54] So would the reductions in MTRs considered in this paper lead to reception charges for mobile subscribers, and would this increase or decrease economic efficiency and social welfare?

The literature on this subject is still in its infancy, so no definite answer can be given. Jeon *et al.* (2004, pp. 105-107) analyze duopoly competition with network-based price discrimination and reception charges and show that for $\beta < 1$, in any symmetric equilibrium off-net reception charges are either infinite or equal to $c_t - a$ depending on parameter values. For reasonable parameter values, Bill & Keep can lead to reception charges so high that no off-net calls are made. Hermalin and Katz (2009), on the other hand, consider a model in which the strategic motive for increasing off-net prices is absent, implying that networks always set off-net sender and receiver prices equal to “perceived” marginal cost, c_0+a and c_t-a, respectively. Thus if Bill & Keep were adopted ($a = 0$), the total cost of an off-net call would be divided between the sender and receiver in proportion to the costs incurred on each network. The two models therefore lead to strikingly different predictions concerning profit-maximizing sender and receiver charges for given termination charges, and Hermalin and Katz (2009, p. 30) remark that, “*the importance of such cross-carrier effects is an empirical question that remains to be answered*”.[55]

Whatever the theoretical predictions, as noted by Harbord and Pagnozzi (2010, Section 6), existing empirical evidence suggests that mobile networks in Bill & Keep countries do not set very high reception charges. Ofcom (2009a, Annex 9) presents evidence on sender versus reception charges in the United States, and finds that “*all operators for all levels of output charge the same price for both types of calls.*” Analysys Mason (2008) found that while all Bill & Keep countries have RPP retail charging regimes, there exist free

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

[55] Lopez (2011) obtains results which are broadly consistent with those of Jeon *et al.* (2004). He finds that connectivity breakdown is prone to occur when networks distinguish between on-net and off-net call and reception charges. Cambini and Valletti (2008), on the other hand, find that networks’ incentives to use off-net/on-net price discrimination to induce connectivity breakdown are reduced when outgoing and incoming calls are complements (specifically, in a model in which each outgoing off-net call results in a fraction $x < 1$ of incoming calls).

incoming call plans in each of these jurisdictions, whose relative importance appears to increase over time (p.4). Hence, as an empirical matter, it is unclear that the adoption of Bill & Keep would necessarily lead to the imposition of significant reception charges for mobile calls.

6 Analysis of the Orange/T-Mobile Merger

Another application of our 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 end of 2009 data, 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 calibrated welfare 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 (MSMs) 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 if the merger had not occurred.

As described in detail in Section 3, 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.[56] This means that the number of brands and the consumer preference space remain unchanged in the Hotelling model before and after the merger. Thus welfare and market outcomes pre- and post-merger can be consistently compared.

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

[56] 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).

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.[57]

6.1 Effects of the Merger under 2010/11 MTRs:

We first consider the changes in mobile firms' market shares caused by the merger. In Table 6.1 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 data 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 almost perfectly for values of β close to 0.75. This result may yield a rough indication of the relevant value of the call externality parameter.

Table 6.1 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	4.92	5.10	5.46	6.12	7.35	6.1
Vodafone	24.8	22.83	22.88	23.04	23.36	23.94	23.46
O2	29.9	27.99	28.01	28.10	28.29	28.58	27.92
Orange	19.4	22.27	22.14	21.84	21.26	20.21	21.04
T-Mobile	19.1	22.00	21.87	21.56	20.97	19.92	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 6.2). 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. 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

[57] 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.

charges for off-net calls on the smaller networks, as well as incurring different Hotelling "transport" costs. 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 3.4). The overall effect is a welfare loss of £321 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.[58]

Table 6.2 Merger Effects with 2010/11 MTRs

Change in	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Welfare	-321	-374	-524	-911	-1933
Consumer Surplus	-1284	-1259	-1249	-1283	-1395
Profits	963	885	725	373	-538

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.

6.2 Effects of the Merger with Bill & Keep

If we perform our calculations with much lower MTRs, such as those proposed in the European Commission *Recommendation* and recently adopted by Ofcom, the (negative or positive) effects of the merger on aggregate welfare are much reduced. 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 £2 million per year, or may even have increased it by up to £23 million, depending on the value of β (see Table 6.3). If we allow for the companies' claimed cost savings of £390 - £420 million per year (see Annex B), this means that the merger would have been welfare improving for all assumed values of the call externality parameter.

[58] Our estimate of the merger's expected annual cost savings is based on information provided in Orange and T-Mobile (2009). The calculations are detailed in Annex B.

But the merger still would have resulted in large decreases in consumer surplus for all values of β, exceeding £900 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 6.3 Merger under Bill & Keep

Change in	$\beta = 0$	$\beta = 0.25$	$\beta = 0.5$	$\beta = 0.75$	$\beta = 1$
Welfare	-2	3	8	14	23
Consumer Surplus	-913	-909	-909	-918	-959
Profits	912	911	917	932	983

6.3 Discussion

Our analysis shows that with MTRs set at their regulated levels for 2010/11, the aggregate effects of the Orange/T-Mobile merger depend on the strength of call externalities. By moving more subscribers on to a single large network, the merger improves allocative efficiency and welfare for low values of the call externality parameter if we allow for the "synergies" or cost savings posited by the merged firms. This observation provides a stark illustration of the inefficiencies created by the LRIC+ approach to regulating MTRs. In the absence of call externalities, efficiency and welfare (although not consumer surplus) would be increased even further by a merger of all five of the mobile network operators in the UK market into a single monopoly network, so that all mobile-to-mobile calls became more efficiently-priced on-net calls. When receiver benefits matter, this is result is reversed, so there is a critical level of the call externality parameter for which the merger becomes harmful to allocative efficiency.

With much lower MTRs, such as Bill & Keep, the merger's aggregate effects on welfare and efficiency are much reduced, since off-net call prices are much closer to their efficient level. Nevertheless, the merger significantly reduces competition and consumer surplus in each of the scenarios we have considered. Under the 2010/11 levels of regulated MTRs, these losses are exceed £1.2 billion per annum for all values of β. Under Bill & Keep, the consumer surplus losses still exceed £900 million per annum.

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 calibrated model, however.

Our model could obviously also be used to analyze the effects of other mobile mergers such as the recently abandoned acquisition of T-Mobile in the United States by AT&T,

or a potential merger between T-Mobile and Sprint.

7 Conclusions

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 £990 million to £4.5 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

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

[2] ARCEP (2008). *Les Référentiels de Coûts des Opérateurs Mobiles en 2008*, Paris.

[3] Armstrong, M. (2002). 'The theory of access pricing and interconnection', in (M. Cave, S. Majumdar and I. Vogelsang eds.), *Handbook of Telecommunications Economics*, Amsterdam: North-Holland.

[4] Armstrong, M. and Wright, J. (2007). 'Mobile call termination in the UK', *MPRA Paper* Number 2344, University Library of Munich, Germany.

[5] Armstrong, M. and Wright, J. (2009a). 'Mobile call termination', *Economic Journal*, vol. 119, pp. F270–F307.

[6] Armstrong, M. and Wright, J. (2009b). 'Mobile call termination in the UK: a competitive bottleneck?' in (B. Lyons ed.), *Cases in European Competition Policy: The Economic Analysis,* Cambridge: CUP.

[7] Berger, U. (2004). 'Access charges in the presence of call externalities', *B.E. Journal of Economic Analysis & Policy*, vol. 3(1).

[8] Berger, U. (2005). 'Bill-and-keep vs. cost-based access pricing revisited', *Economics Letters*, vol. 86(1), pp. 107-112.

[9] 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*, vol. 1, pp. 49-72.

[10] 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*, vol. 39, pp. 50-67.

[11] 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.

[12] Budzinski, O. and I. Ruhmer (2010). 'Merger simulation in competition policy: a survey´, *Journal of Competition Law & Economics*, 6 (2), pp. 277-320.

[13] Cabral, L. (2011). 'Dynamic price competition with network effects', *Review of Economic Studies,* vol. 78, pp. 83–111.

[14] Calzada, J. and Valletti, T. (2008). 'Network competition and entry deterrence', *Economic Journal*, vol. 118, pp. 1223-1244.

[15] Cambini, C. and Valletti, T. (2008). 'Information exchange and competition in communications networks', *The Journal of Industrial Economics*, vol. 56, pp. 707-728.

[16] Carter, M. and Wright, J. (1999). 'Interconnection in network industries', *Review of Industrial Organization*, vol. 14, pp. 1-25.

[17] Carter, M. and Wright, J. (2003). 'Asymmetric network interconnection', *Review of Industrial Organization*, vol. 22, pp. 27-46.

[18] 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.

[19] Competition Commission (2009). *Mobile phone wholesale voice termination charges: Determination*, HMSO, London.

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

[21] DeGraba, P. (2003). 'Efficient intercarrier compensation for competing networks when customers share the value of a call', *Journal of Economics and Management Strategy*, vol. 12, pp. 207-230.

[22] Dewenter, R. and Haucap, J. (2005). 'The effects of regulating mobile termination rates for asymmetric networks', *European Journal of Law and Economics*, vol. 20, pp. 185-197.

[23] Dewenter, R. and Haucap, J. (2007). 'Demand elasticities for mobile telecommunications in Austria', Ruhr Economic Papers, No. 17.

[24] 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*, vol. 5.2.2004, pp. C31/5 - C31/18.

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

[26] 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.

[27] 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.

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

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

[30] 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*, vol. 7, pp. 133–137.

[31] Gans, J. and King, S. (2001). 'Using 'bill and keep' interconnect arrangements to soften network competition', *Economics Letters*, vol. 71(3), pp. 413-420.

[32] Genakos and Valletti, T. (2011). 'Testing the 'waterbed' effect in mobile telephony', *Journal of the European Economic Association*, vol. 9, pp. 1114-1142.

[33] 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,* vol. 9(1), Article 1.

[34] Hermalin, B. and Katz, M. (2009). 'Customer or complementor? intercarrier compensation with two-sided benefits', *Journal of Economics and Management Strategy*, forthcoming.

[35] Hoernig, S. (2007). 'On-net and off-net pricing on asymmetric telecommunications networks', *Information Economics & Policy*, vol. 19(2), pp. 171-188.

[36] Hoernig, S. (2008). 'Tariff-mediated network externalities: is regulatory intervention any good?' CEPR Discussion Paper No. 6866.

[37] Hoernig, S. (2009). 'Market penetration and late entry in mobile telephony', mimeo, FEUNL, January.

[38] Hoernig, S. (2010). 'Competition between multiple asymmetric networks: theory and applications', CEPR Discussion Paper 8060, October.

[39] Hotelling, H. (1929). ‘Stability in Competition’, *Economic Journal*, vol. 39, pp. 41-57.

[40] Hutchison 3G UK Limited (2009). *Response to Wholesale Mobile Voice Call Termination Preliminary Consultation on Future Regulation*, 29 July 2009.

[41] Ivaldi, M. & F. Verboven (2005a). ‘Quantifying the Effects from Horizontal Mergers in European Competition Policy’, *International Journal of Industrial Organization*, 23, pp. 669-691.

[42] Jeon D., Laffont, J.-J. and Tirole, J. (2004). ‘On the receiver pays principle’, *RAND Journal of Economics*, vol. 35, pp. 85 -110.

[43] Laffont, J.-J., Rey, P. and Tirole, J. (1998). ‘Network competition: II. price discrimination’, *RAND Journal of Economics*, vol. 29(1), pp. 38-56.

[44] Lopez, A. (2011). ‘Mobile termination rates and the receiver-pays regime’, *Information Economics & Policy*, 23 (2011) 171–181.

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

[46] Ofcom (2007b) *The Communications Market 2007*, Office of Communications, London.

[47] Ofcom (2008) *The Communications Market 2008*, Office of Communications, London.

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

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

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

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

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

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

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

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

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

[57] 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.

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

[59] Thompson, H., Renard, O., and Wright, J. (2007). 'Mobile termination', in (J. Haucap and R. Dewenter eds.), *Access Pricing: Theory and Practice*, Amsterdam: Elsevier.

[60] Valletti, T. and Houpis, G. (2005). 'Mobile termination: what is the 'right' charge?' *Journal of Regulatory Economics*, vol. 28, pp. 235-258.

[61] Vogelsang, I. (2010), 'The relationship between mobile and fixed line communications: a survey', *Information Economics and Policy*, vol. 22 (1), pp. 4-17.

[62] Wright, J. (2002). 'Access pricing under competition: an application to cellular networks', *Journal of Industrial Economics*, vol. 50, pp. 289-315.

Annex A 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. The equilibrium market shares will then be determined in a second step. This procedure is without loss of generality but simplifies the derivation of call prices.

Given uniform off-net prices, a non-merged firm i chooses the three prices p_{ii}, p_{ij} and p_{if}, while holding $\sum_{j\neq i}(w_i - w_j)$ constant by adapting F_i. Thus, using $dv_{ij}/dp_{ij} = -q_{ij}$ and $du_{ij}/dp_{ij} = p_{ij}q'_{ij}$, we have

$$\begin{aligned}\frac{dF_i}{dp_{ii}} &= M\alpha_i(\beta p_{ii}q'_{ii} - q_{ii}),\ \frac{dF_i}{dp_{if}} = -Nq_{if},\\ \frac{dF_i}{dp_{ij}} &= -M[(1-\alpha_i)\,q_{ij} + \alpha_i\beta p_{ij}q'_{ij}].\end{aligned}$$

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

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

The resulting call prices are

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

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 FTM price p_{if} 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 are non-trivial. The merged network chooses its prices p_{12} and p_{1j} while adjusting F_1 and F_2 as to keep $\sum_{j\neq 1}(w_1 - w_j)$ and $\sum_{j\neq 2}(w_2 - w_j)$ constant (the determination of p_{21} and p_{2j} follows the same logic). Thus for calls between networks 1 and 2,

$$-(n-1)\left(M\alpha_2 q_{12}+\frac{dF_1}{dp_{12}}\right)-M\alpha_1\beta p_{12}q'_{12}+\frac{dF_2}{dp_{12}}=0$$
$$(n-1)\left(M\alpha_1\beta p_{12}q'_{12}-\frac{dF_2}{dp_{12}}\right)+M\alpha_2 q_{12}+\frac{dF_1}{dp_{12}}=0,$$

which has solution

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

and for calls to other networks

$$-(n-1)\left(M\left(1-\alpha_{1+2}\right)q_{1j}+\frac{dF_1}{dp_{1j}}\right)+\frac{dF_2}{dp_{1j}}-(n-2)\,M\alpha_1\beta p_{1j}q'_{1j}=0,$$
$$-(n-1)\frac{dF_2}{dp_{1j}}+\left(M\left(1-\alpha_{1+2}\right)q_{1j}+\frac{dF_1}{dp_{1j}}\right)-(n-2)\,M\alpha_1\beta p_{1j}q'_{1j}=0,$$

with solution

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

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 $\tilde{c}_{1j}=\sum_{l\neq 1,2}\alpha_l c_{1l}/(1-\alpha_{1+2})$)

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

The resulting profit-maximizing call prices are

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

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 set based on the merged networks' joint market share.

Subscription fees: We now determine the Nash equilibrium through networks' choice of subscription fee. First note from the market share equation (1) that the effect of fixed fees on market shares is given by

$$\frac{d\alpha_j}{dF_i}=-\sigma H_{ji}.$$

A non-merging firm i maximizes π_i, which has first-order condition

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

or

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

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

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

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 $i = 1, 2$,

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

The resulting fixed fees are again given by the above expression, where now

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

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

Annex B Efficiency Gains from the Orange/T-Mobile Merger[59]

Orange and T-Mobile forecast efficiency gains totalling £545m a year from 2015 onwards.[60] However in the preceding years 2010 to 2014, forecast annual gains are generally lower than this due to implementation costs and the phasing-in of savings. Orange and T-Mobile forecast:

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

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

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

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

[60] 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.

calculated the level annuity which, over that same forecasting horizon, would also generate an NPV of £3.5bn.

Our results are shown below:

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