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Abstract

International roaming – the ability to use one's mobile phone on foreign networks – has contributed to the success of GSM services in Europe, but has also been a constant concern for competition authorities. Whilst competition for subscribers has driven down the cost of owning and using mobile phones, roaming charges have remained high, and have been the subject of investigation for example by the European Commission.

However, in order to see whether high roaming charges are indeed the result of failing competition, and in order to identify appropriate remedies, one needs to understand how technological constraints impact on competition in the provision of roaming services. In particular, the limited ability to direct roaming traffic onto a particular network, combined with the need for multiple contracts in order to be able to offer continued coverage, implies that price competition at the level of inter-operator tariffs (IOTs) is muted.

In this paper, we model competition in the provision of wholesale roaming services, and its implications for retail offers, depending on the ability to direct roaming traffic onto particular partner networks. We examine the impact of cross-border mergers which are often seen to improve an operator's ability to offer seamless roaming service across an increasing number of countries as a result of an enlarged footprint.

Keywords: international roaming, competition, internalisation
JEL classification: D43, L13, L42, L96

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1 Introduction

Over the last few years, mobile penetration in Europe has soared and an ever larger proportion of the population now enjoys the benefits of being able to make and receive calls and use other services such as SMS wherever they are. By 2001[1], average mobile penetration in the European Union exceeded 70%, and is expected to grow further still.

This growth has been accompanied by a dramatic fall in prices of most mobile services. However, despite the overall downward trend of mobile tariffs, and the increasing range of customers who take advantage of the ability to use their mobile phones abroad, international roaming charges have remained high. Although there is a widely shared view that the roaming capabilities available to GSM users have played an important role in the growth of mobile, the apparent reluctance of mobile operators to lower roaming tariffs has caused concerns amongst mobile customers, consumer associations, regulators and competition authorities. Why has competition, which has brought about a significant reduction in overall mobile prices, not been effective in the case of roaming?

The apparent lack of competitive pressure on international mobile roaming charges led the European Commission to launch a sector inquiry in July 1999. The preliminary findings of this inquiry can be summarised as follows: [2]

- In assessing the competitive constraints on roaming charges, it is necessary to examine at least two distinct relevant markets, namely a wholesale market (in which operators purchase roaming services from each other) and a retail market (in which roaming services are provided to end customers). Both markets are considered to be national.
- The Commission regarded the fact that different mobile operators in many national markets charge almost identical wholesale rates, and that in some of these markets operators also apply similar retail tariffs, as evidence of co-ordinated pricing behaviour or tacit collusion, supporting the view that collusion is the likely source of excessive pricing in both markets.
- The Commission was concerned about high barriers to entry (especially in wholesale markets) due to limited number of licences per country.
- The Commission also noted that prices appeared not to be cost oriented as:

[1] European Commission, *7th Report on the Implementation of the Telecommunications Regulatory Package*, 2001, available online at http://europa.eu.int/information_society/topics/telecoms/implementation/annual_report/7report/documents/7report2001.pdf

[2] European Commission, *EC Working Document on the initial findings of the sector inquiry into mobile roaming charges* of 13 December 2000 (the *EC Working Document*), available online at http://europa.eu.int/comm/competition/antitrust/others/sector_inquiries/roaming/working_document_on_initial_results.pdf.

- differences in wholesale prices across Member States during 1997-2000, although decreasing over time, were too large to be justified by cost differences; and
- on average, wholesale tariffs, and thus retail prices (which are normally calculated by applying a mark-up to wholesale charges), have been rising[3]. This was in sharp contrast to the general fall of domestic retail prices.

However, as we argue in this paper, there are alternative explanations for persistent high roaming charges which can explain why these charges have been largely immune to competitive pressure. Moreover, the factors that have been responsible for high roaming charges are currently changing, and one might expect the general downwards trend in mobile tariffs to extend into the world of roaming in the (near) future.

More specifically, the limited ability of mobile network operators (MNOs) to direct the roaming traffic of their subscribers onto a particular network may be the main reason for the remarkable failure of competition to bring down roaming charges. This is because in the absence of roaming traffic being directed onto the cheapest network[4] the effective price perceived by roaming customers is based on an average of all wholesale charges. This implies that:

- the impact of a price cut on demand will be diluted, causing only a very limited impact on the level of demand faced by that network;
- if one operator reduces its wholesale charges, other MNOs may benefit from increased demand without having reduced their prices; and
- it may even be possible that other MNOs respond by *increasing* their wholesale charges.

These problems are exacerbated by *retail tariffs* being complicated and often not very transparent to consumers[5]. A subscriber generally faces a plethora of

[3] According to the *EC Working Document*:

> *"Most operators that had the lowest wholesale tariffs in 1997 have raised their tariffs gradually over the period 1997-2000, while most of the operators with relatively high have lowered their tariffs. Hence, over the period under review, wholesale tariffs have clearly converged towards a higher overall level that does not appear to bear any relation to cost."*

[4] A subscriber to a given mobile operator A roaming on another network B would pay a retail roaming price to A, who then pays a wholesale tariff to operator B. Typically, the retail price paid by the subscriber depends on the applicable wholesale tariff, and hence on the network on which the subscriber is roaming.

[5] The lack of transparency of retail roaming prices has been presented in many INTUG (*International Telecommunications User Group*) position papers and speeches. See for instance the *Global roaming* INTUG position paper of 07/2000, available on-line at http://www.intug.net/views/roaming.html, or Sutherland, E, (INTUG), February/March 2001, 'International roaming charges: overcharging and competition law', *The International Journal on Knowledge Infrastructure Development, Management and Regulation*, (25)½, available on-line at http://www.tpeditor.com/contents/2001/sutherland.htm.

different tariffs that vary across countries in which roaming is possible, and within each country across the networks to which a roaming customer might connect. Add to that the general differentiation between peak and off-peak (evening and week-end) tariffs (with peak and off-peak periods changing across countries) and differences in billing increments, and it is clear that roaming customers may often not have sufficient information to select the cheapest available network. For this reason, demand for roaming services is more likely to be driven by some notion of average price – based on previous bills – than by actual retail prices for each individual visited network.

In this paper we analyse the impact of the technological and institutional constraints within which MNOs set roaming charges – both wholesale and retail tariffs – and how changes in these conditions may lead to changes in the level of these charges. We also examine the competitive implications of introducing simplified offers at the retail level. The remainder of this document is structured as follows:

In section **Error! Reference source not found.** we present a brief description of roaming services, and discuss technical aspects that place constraints on competition. In section 3 we introduce a model to explain price setting mechanisms and the effect of changes in the competitive environment on market outcomes. We start with a simple base case that captures the lack of price competition in the market for roaming services. In this base case wholesale demand is unaffected by price differentials as we assume that:

- consumers are unaware of applicable tariffs for roaming on different networks; and
- that operators do not have the required technology for directing traffic to a specific network.

We further assume that retail roaming prices are not subject to competitive pressure. Whilst clearly an extreme case, this assumption captures a situation where retail roaming charges are sufficiently opaque so as not to play a significant role in a subscriber's choice between networks. Varying the assumptions in the base case, we then analyse the effect of:

- introducing competition amongst retail operators;
- asymmetric default shares of roaming traffic; and
- the impact of cross-border mergers (leading to 'vertical' integration across the wholesale and retail market).

We then analyse the impact of traffic redirection, either manually by the subscriber as a result of enhanced price transparency in simplified calling plans (such as the Eurocall pan-European tariff recently launched by the Vodafone group), or automatically through SIM-based selection of the roaming network.

We present our conclusions in section 4.

2 Background

2.1 What is roaming?

In general terms, roaming is the ability of a subscriber to a particular network to use the mobile phone on another operator's network. This requires a roaming agreement between the networks and an exchange of information between these networks for authentication and billing purposes.[6]

In this paper we are concerned with international roaming[7] - i.e. the ability to use one's mobile phone abroad. We refer to the mobile network operator to which the mobile user subscribes as the *home operator/network*. We call the operator supplying roaming services to users out of their home country the *visited operator/network*.

The GSM Association Memorandum of Understanding (MoU), establishing common standards across national operators, is the basis for international roaming[8]. The GSM Association *Standard Terms for International Roaming Agreement* (STIRA), which were introduced in 1996, provide the framework and tariffing principles for roaming agreements between GSM Association members and thus facilitates the negotiations between operators. A common accounting protocol (TAP3) supports the setting of inter-operator tariffs (IOTs) – the wholesale charges paid to the visited operator by the home network for traffic generated by its subscribers roaming on the visited network. These agreements are usually reciprocal, i.e. in

[6] Given the increasingly large number of roaming agreements required in order to offer universal roaming capabilities to its subscribers, smaller networks (new entrants) often rely on the services of roaming 'brokers' – operators who allow others to benefit from their roaming agreements by re-selling roaming minutes. This essentially turns the customer of the broker into a service provider of the broker. However, brokers do not seem to put any competitive pressure on wholesalers and hence we leave them out of the analysis in this paper.

[7] There is also national roaming, where operators without full national coverage may rely on other networks in areas where they lack coverage. National roaming is, however, the exception rather than the rule (although it may become more important in a 3G environment, both in terms of 2G/3G roaming and attempts to avoid wasteful duplication of network investments. The issues related to national roaming are rather different from the ones considered here. For a discussion of national roaming see Valletti, T, 2001, *Is mobile telephony a natural Oligopoly?*, mimeo, available on-line at http://www.ms.ic.ac.uk/tommaso/natural.pdf.

[8] A description of roaming agreements can be found, for example, in Sutherland, E. (INTUG) *International roaming charges: overcharging and competition law*, The International Journal on Knowledge Infrastructure Development, Management and Regulation, Vol. 25, No. ½ (February/March 2001), available on-line at http://www.tpeditor.com/contents/2001/sutherland.htm.

order to generate roaming traffic on its network an MNO usually needs to agree to have its subscribers roam onto the partner network.[9]

2.2 Wholesale and retail roaming markets

When looking at roaming services and roaming charges, we can distinguish between the wholesale market for roaming services where network operators enter into roaming agreements with each other, and retail markets where network operators compete for roaming traffic essentially by competing for subscribers.[10] Both markets may be considered to be national in scope, and in particular the wholesale market is characterised by a low number of suppliers (network operators) and high barriers to entry because of radio spectrum constraints. However, because barriers to expansion are low, this does not necessarily imply that competition is weak: each operator has both a strong incentive and the ability to increase the traffic load on its network thereby exploiting economies of scale and scope.[11]

Up to 1998, charges in the wholesale market were based on the Normal Network Tariffs (NNT) charged by MNOs – in essence the same tariffs as for domestic calls with a mark-up (capped at 15%) to account for the lack of subscription revenues from roaming mobile phone users. Under the NNT regime, competitive pressure on call prices for domestic users directly translated into lower roaming charges. However, NNTs increased over time as operators chose the highest call tariffs as reference points, switching from business to residential tariffs. In 1998, the NNT regime was replaced by MNOs setting specific Inter-Operator Tariffs (IOT) which are decoupled from domestic call charges.

Current IOTs tend to be very similar across operators in a given country, but different across countries. As noted above, this suggests that these tariffs are not directly linked to the underlying costs of providing wholesale roaming services, which should be relatively similar across countries as MNOs are using the same technology. IOTs are highly transparent as they are published by the GSM Association, and they are generally available to all operators, i.e. visited networks do not discriminate between home networks. This is in line with standard non-discrimination obligations imposed by the GSM Association on its members.

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[9] Valletti examines the incentives for MNOs to enter into roaming agreements depending on whether or not they are competing with each other (associated with national and international roaming respectively). He finds that firms are unlikely to have an incentive to enter into national roaming agreements given that differences in coverage are an important dimension of quality differentiation, but that international roaming is in the interests of MNOs having 'captive' customers. See Valletti, T., 1998, *Competition in Mobile Telephony: Network Coverage and Roaming*, mimeo, paper presented at the EARIE 1998 conference in Copenhagen.

[10] Note that once a subscriber has signed up with a home network it will not in general have a choice of purchasing roaming services from other home networks.

[11] The importance of low barriers to expansion for the competitiveness of the mobile sector has been pointed out in the judgment of *Mr. Justice O'Higgins* in *Meridian Communications Limited and Cellular Three Limited* versus *Eircell Limited* (*Irish High Court Judgment, 1999 No 5306p*, delivered on 5 April 2001).

However, the combination of transparency and non-discrimination is often feared to dampen competition and facilitate collusion.

Home operators then mark up the visited network's IOT in order to arrive at a retail price for roaming services. All operators in a given country usually apply the same or very similar mark-ups.

With respect to receiving calls when roaming abroad, the calling party pays for the standard call to the home network of the roaming subscriber. The subscriber roaming abroad pays for the cost of redirecting that call to the visited country and terminating it on the visited network.

Independent service providers (ISPs) depend on roaming services resold by licensed operators in their home country, and they share the mark-up on the IOT with the licensed operator. The European Commission found mark-ups to be highest where independent service providers play a significant role (e.g. in Germany).

Demand for roaming services is often considered not to be particularly price sensitive for the following reasons:

- Price transparency is weak: roaming customers will not have full information about the range of roaming tariffs available in different countries on different networks. [12]
- Roaming charges may not play a prominent role in subscribers' network choice as roaming may account for only a small proportion of the total use of mobile telephony.

However, both of these factors are likely to change:

- There have been attempts recently to increase price transparency to final users. A number of operators have introduced average roaming prices: some provide a fixed rate for a given country – regardless of the visited network; some are intending to offer uniform flat rates for calls made from other countries to the home country. Other operators focus on tariff plans that provide incentives for manual selection, for example the Vodafone Eurocall plan.[13] Simplified price plans should enable mobile subscribers to

[12] The lack of information on roaming charges is the focus of numerous INTUG position papers about roaming (see footnote 5 above).

[13] This plan is based on reciprocal quantity-related IOT discounts, conditional on the home operator offering its subscribers a uniform tariff for roaming in all countries covered by the plan. The uniform tariff consists of a special tariff that applies when roaming on a network that participates in the Eurocall plan, and a basic tariff that applies when roaming on any other non-participating network. Each participating operator can set the special and basic tariffs applying to its subscribers. However, the scheme specifies that the special tariff must be below the basic tariff and subject to a cap of €0.80 per minute. The Eurocall and IOT discount scheme by Vodafone Ltd. was notified to the European Commission in Case COMP/C1/38.074 under Regulation 17/62 on 1 February 2001. The notification is reported in the *Official Journal of the European Communities, C42* Vol. 44, 8 February 2001. Further details on the scheme and a summary of the plan are available at http://www.vodafone.com/regulatory.

make better informed comparisons between offers when choosing the home operator. However, such tariffs may also reduce any incentives there might be for customers to select the cheapest network when roaming abroad compared to a situation where retail operators simply impose uniform mark-ups on IOTs.

- The use of roaming services has become more widespread amongst mobile users (extending to prepay customer who initially were not able to use their phones whilst travelling abroad). Given the overall fall in mobile retail prices and an increased focus on roaming, retail roaming charges may become more important in competing for subscribers (in particular where they can be simplified).

2.3 Network selection

To understand the nature of the relationship between supply and demand of roaming services, we need to take a brief look at how mobile users connect to a visited network and what options exist for selecting a particular network when roaming.

As MNOs tend to have roaming agreements with a number of network operators in other countries, a roaming customer generally can connect to different visited networks when roaming.[14] When leaving the area covered by the home operator, the subscriber's handset will detect all available networks and automatically select one. Additional to this, most handsets allow users to override this automatic selection and select a network manually.

Automatic selection of networks is driven by:

- *Last network prevalence* – Once connected to a visited network, the handset will remain connected until the signal is lost or the user manually selects another network. When the phone is switched off and back on again, it will re-connect to this network, provided coverage is available.

- *SIM selection* – SIM cards have a list of preferred networks. When the last network that has been used is not available, the handset will work through this list and connect to the first available network. If none of the networks on the preferred list is available, the network will be selected by the handset as detailed below. Roaming agreements may include obligations to grant the visited network a preferred roaming status by including it in the SIM-card list of preferred networks (at the highest position of all networks within a particular country). Such agreements are often reciprocal, although unilateral obligations also exist – usually imposed by large operators in one country when negotiating roaming agreements with smaller operators in other countries.

[14] This is in contrast to using a mobile phone in the home country, where in the absence of national roaming agreements a connection can only be made to the network to which a mobile phone user subscribes.

However, SIM selection via a preferred list is relatively limited for a number of reasons:

a) some handsets appear to overwrite the list when a user manually selects a network, by placing this network at the top of the list;

b) the list is too small to hold information on preferred networks for all countries in which roaming is possible.

Compared to a static list of preferred networks, the new SIM Application toolkit and SIM-over-the-air programming technology increases the possibilities of SIM-based traffic redirection. The new technology allows operators to modify the list of preferred networks at any point in time.[15]

- *Handset selection* – handsets feature procedures for selecting a network in the event that none of the networks in the preferred list is found. These procedures are generally based on the strength and quality of signals received from different networks.

Unless the subscriber manually chooses the visited network or the home network operator can ensure that the handset connects to a particular network whenever possible, the choice of visited network is largely random and the average roaming charge paid by the subscriber is an average of the retail roaming charges set by the home operator for the visited networks with which it has roaming agreements.

The only option for the home operator to direct traffic onto a particular network would be to enter into an exclusive roaming agreement. This would force roaming customers to connect to a single visited network chosen by the home operator. However, this option is unlikely to be attractive because:

- it would have an impact on the quality of roaming services perceived by subscribers, given that fewer networks would be available for roaming, with an increased likelihood of being without roaming coverage; and
- because of reciprocity, the home operator would loose roaming traffic on its network, which is particularly important since revenues from wholesale roaming are generally much larger than revenues from retail roaming activities.

3 A model of setting IOTs and retail prices for roaming services

In this section we develop a simple model that allows us to investigate the way in which IOTs and retail prices are set. In general, every operator is both a retailer (selling roaming services to its own subscribers) and a wholesaler (allowing the customers of operators in other countries to connect to its network when abroad).

[15] *EC Working Document*, and Stumpf, U, 2001, *Prospects for improving competition in mobile roaming*, WIK available on-line at http://www.wik.org/content_e/tprc_stu.pdf

However, these two activities are unrelated – the IOTs set by an operator will not impact on the retail rates set by the same operator.[16]

For simplicity we consider the case of two retail operators in one country and two wholesale operators in another country. However, the model can easily be generalised from the 2 operator × 2 countries set-up.

3.1 Demand for roaming services

Wholesale demand for roaming services is derived from retail demand. The roaming demand faced by any particular visited network depends on (a) the number of subscribers to a particular home network that (b) roam on the visited network. Customers first choose the home network and may choose the visited network (when roaming).

However, when price differences across visited networks are unknown, subscribers may not actually choose a particular visited network, but leave the choice of network to chance (with the handset effectively selecting the network to which to connect). Indeed, users do not usually manually select networks but connect to the handset's default choice. This implies that the choice of home network by mobile users is based on the weighted average retail roaming prices set by each home operator, where the weights are determined by the distribution of roaming traffic across visited networks.[17]

We define α_i as the share of roaming traffic generated by subscribers of home network *i* going to visited operator 1 by default, i.e. without the customer manually selecting the visited network. The shares of roaming traffic by subscribers to home operator *i* to different visited operators *j*, $s_{i.j,}$ are therefore:

$$s_{i1} = a_i$$
$$s_{i2} = (1 - a_i)$$

Let $p_{i,j}$ be the retail price for subscribers to home operator *i* roaming on visited network *j*. We can now obtain the average retail price (P_i) paid for roaming services by subscribers of home operator *i* as the weighted average of retail prices for each visited network:

$$P_i = a_i p_{i1} + (1 - a_i) p_{i2}$$

[16] In reciprocal relationships between operators, each providing roaming services to the other, this may not be true to the extent that both operators sustain particular levels of IOTs in a repeated game. In this case, one operator's IOT would be linked to its own retail roaming charge by virtue of being linked to the other operator's IOT. However, the relevance of this possibility is limited in a world of universal roaming and non-discrimination between home operators with respect to IOTs.

[17] These assumptions are relaxed below when we study the impact of calling plans designed to incentivise manual selection. In this case we will assume that mobile users always select the cheapest visited network.

Assuming that default network selection is effectively random, and that all visited networks have similar coverage, the share of roaming traffic α_i would be the same for all operators in the visited country – in our case one half – and $P_i = \frac{p_{i1} + p_{i2}}{2}$.

Roaming services are only one element of the bundle of mobile services available to subscribers, and therefore we would not expect the choice between mobile networks to be affected solely by roaming charges. Thus, we model competition between home operators for roaming traffic as differentiated Bertrand competition. More specifically, we assume that retail demand for roaming faced by each operator is a linear function of its own average retail price and the other operator's average retail price:

$$d_1 = A - b\,P_1 + g\,P_2$$
$$d_2 = A - b\,P_2 + g\,P_1$$

with $b = e + g$. Setting $\gamma = 0$ captures the case where differences in roaming charges are irrelevant for the choice between home operators. $\gamma = 0$ captures an extreme case where customers are completely unaware of differentials in roaming prices set by alternative home operators, or where roaming prices are irrelevant in subscribers' choice of home network. e can be interpreted as the overall market price sensitivity of roaming demand.

We denote as $d_{i,j}$ the demand for roaming minutes on visited network *j* generated by subscribers of home operator *i*.

Applying the shares given above to total roaming demand generated by home operator *i*'s subscribers, we obtain:

$$d_{ij} = d_i \cdot s_{ij}$$

The aggregate wholesale demand faced by each visited operator *j* is then:

$$d^{w}{}_{j} = d_1 \cdot s_{1j} + d_2 \cdot s_{2j}$$

3.2 Base case

We first consider the case of independent firms unable to direct roaming traffic onto a particular visited network. We assume that consumers are insufficiently aware of the different levels of roaming charges to respond to price differentials for both:

- price differentials between visited networks – implying automatic handset rather than manual network selection; and
- price differentials between home operators – implying $\gamma = 0$ (and thus = ε).

Assuming symmetry between networks, default shares of roaming traffic are $_{i}$ = ½, for *i* = 1, 2.

Operators set their price to maximise profits. We consider the following two-stage price setting game:

- first, each visited network j sets a non-discriminatory IOT w_j;
- second, each home network i sets retail prices by applying a uniform mark-up m_i to the IOTs set by the visited networks.

Given IOTs w_1 and w_2, the retail prices set by firm i will be p_{i1} = (1+ $_i$)w_1 and p_{i2} = (1+ $_i$)w_2 respectively.

The demand for roaming services depends on the average retail price offered by home operators, i.e. $P_i = \frac{w_1 + w_2}{2} \cdot (1 + m_i)$.

Demand faced by home operator i is given by:

$$d_i = A - e \cdot \frac{w_1 + w_2}{2} \cdot (1 + m_i)$$

and the wholesale demand faced by visited network j operators is:

$$d^w{}_j = d_{1j} + d_{2j} = \frac{1}{2} \cdot (d_1 + d_2)$$

We solve for optimal prices by backwards induction.

2nd stage – home operators set retail mark-ups

For the sake of simplicity we normalise the marginal cost faced by the retail operator to zero. Each retail operator sets its mark-up to maximise profits, which are given by:

$$p^r{}_i = d_{i1} \cdot (p_{i1} - w_1) + d_{i2} \ (p_{i2} - w_2)$$

$$= d_{i1} \cdot (m_i \cdot w_1) + d_{i2} \cdot (m_i \cdot w_2)$$

$$= d_1 \cdot m_i \cdot \frac{w_1 + w_2}{2}$$

$$= \left(A - e\,(1 + m_i) \frac{w_1 + w_2}{2} \right) \cdot m_i \cdot \frac{w_1 + w_2}{2}$$

The profit maximising mark-ups are then given by:

$$m_i = m^* = \frac{A - e\,\frac{w_1 + w_2}{2}}{e\,(w_1 + w_2)}$$

1st stage – visited operators set IOTs

Assuming that each of the visited networks faces a constant marginal cost c in the provision of roaming services, operator j's wholesale profits are:

$$\begin{aligned}
p^w{}_j &= d^w{}_j \cdot \left(w_j - c \right) \\
&= \frac{1}{2} (d_1 + d_2) \cdot \left(w_j - c \right) \\
&= \frac{1}{2} \left(A - e\,(1 + m_1) \frac{w_1 + w_2}{2} + A - e\,(1 + m_2) \frac{w_1 + w_2}{2} \right) \cdot \left(w_j - c \right)
\end{aligned}$$

Substituting the optimal mark-ups we obtain:

$$p^{w}{}_{j} = \frac{1}{2}\left(A - e\frac{w_1 + w_2}{2}\right)\cdot\left(w_j - c\right)$$

Solving for optimal IOTs in a symmetric equilibrium gives:

$$w_j = w^* = \frac{2A + ec}{3e}$$

This implies the following mark-ups, retail prices, demanded quantities and profits:

$$m_i = \frac{1}{2}\cdot\frac{A - ec}{2A + ec}$$

$$p_{ij} = \frac{5A + ec}{6e}$$

$$d_{ij} = \frac{A - ec}{12}$$

$$p^{r}{}_{i} = \frac{\left(A - ec\right)^2}{36e}$$

$$p^{w}{}_{i} = \frac{\left(A - ec\right)^2}{9e} = 4\cdot p^{r}{}_{i}$$

For $A > ec$ (i.e. as long as there is positive demand for roaming services at marginal cost prices) IOTs and retail prices are above marginal costs[18]. Wholesale operators extract a larger share of overall profits than retailers.

This shows that prices above cost at the wholesale level can arise without tacit collusion simply because differences in IOTs do not lead to differences in the volumes faced by each operator. Indeed, the jointly profit maximising IOT $\tilde{w} = \frac{A + ec}{2e}$ that would result from effective collusion, would be smaller than the IOTs set by independent operators. This is because independent operators impose an externality on each other: by raising its IOT each operator suffers only a proportion (in our case one half) of the consequent reduction in demand, which

[18] Note that a competitive outcome in this case would require prices to be set at cost. For the sake of simplicity we have not included fixed costs incurred in the provision of mobile services which would need to be recovered through mark-ups on marginal costs, and we therefore abstract from the problem of how these mark-ups should be designed to efficiently recover fixed costs across all mobile services. In presence of fixed costs, these would be efficiently recovered by setting Ramsey prices for mobile services, which may yield prices above marginal costs for several services. In our model fixed costs are zero and thus mark-ups on marginal cost of roaming respond to profit maximisation and not to fixed cost recovery. For this reason, setting prices over marginal cost is neither efficient nor optimal from a social perspective.

itself is dampened because the increase in one operator's IOT has a less than proportionate impact on the average IOT and thus the average retail price faced by roaming customers. Therefore, high prices can simply be explained by wholesale operators not being able to increase their market share through lowering their IOTs.

This does of course not mean that MNOs are not competing for roaming traffic – it only means that they do not do so by lowering wholesale charges. Rather, each MNO has incentives to engage in behaviour that increases the default share of roaming traffic on its network, e.g. by improving coverage to make sure that:

- a handset randomly selecting a roaming network is more likely to connect to its network rather than to those of its competitors;
- the network connection of a roaming customer does not drop because it may then reconnect to another network.

This can be achieved by improving coverage and eliminating 'black spots' that would lead to a connection being dropped, with a particular focus on those areas where roaming customers are most likely to be found. Particular attention would be given to places such as airports or border crossings where a roaming customer makes the first connection to the visited network after disconnecting from its home network. This may lead to a coverage 'arms race' in those places.[19]

3.2.1 Competition in the home market

If we relax the assumption that roaming charges do not play a role in competition for subscribers (i.e. > 0), the retail demand faced by home operator *i* is given as:

$$d_i = A - b \cdot \frac{w_1 + w_2}{2} \cdot (1 + m_i) + g \cdot \frac{w_1 + w_2}{2} \cdot (1 + m_j)\ , \ i \quad j$$

where $b = e + g$. In order to assess the impact of competition[20], we assume that the overall market price sensitivity of roaming demand (e) remains constant, and thus that increases with .

2nd stage – home operators set retail mark-ups

Retail profits earned become:

$$p^r{}_i = \left(A - b\,(1 + m_i)\frac{w_1 + w_2}{2} + g\,(1 + m_j)\frac{w_1 + w_2}{2} \right) \cdot m_i \cdot \frac{w_1 + w_2}{2}$$

Solving for the optimal mark-ups in this situation, we obtain:

[19] Note that this is a different point from the one made by Valletti (1998) who examines coverage as a quality parameter so that differences in coverage help MNOs to differentiate their offerings and soften price competition.

[20] In the remainder of this document we will use "more intense competition at the retail level" as shorthand for an increased role of roaming charges in competing for subscribers.

$$m_i = m^* = \frac{A - (b - g)\frac{w_1 + w_2}{2}}{(2b - g)\frac{w_1 + w_2}{2}} = \frac{A - e\frac{w_1 + w_2}{2}}{(2e + g)\frac{w_1 + w_2}{2}}$$

which we see is decreasing with . Competition in the home market has the effect of reducing the best response mark-up that retail operators set on the IOTs.

1st stage – visited operators set IOTs

Profits by wholesale operators are now:

$$p^{w}{}_{j} = \left(A + \frac{(g - b)}{2}\frac{w_1 + w_2}{2}\left((1 + m_1) + (1 + m_2)\right)\right)\cdot\left(w_j - c\right)$$

Substituting the home operators' optimal mark ups results in:

$$p^{w}{}_{j} = \left(A\left(1 + \frac{(g - b)}{(2b - g)}\right) + (g - b)\frac{w_1 + w_2}{2}\left(1 + \frac{(g - b)}{(2b - g)}\right)\right)\cdot\left(w_j - c\right)$$

We can then obtain the optimal IOTs:

$$w_i = w^* = \frac{2A + (b - g)c}{3(b - g)} = \frac{2A + ec}{3e}$$

Optimal IOTs do not depend on . Visited operators do not increase their IOTs in response to a decrease in the mark-ups at the retail stage. This may appear counter-intuitive in the first instance, as one might expect the reduction in retail mark-up, which reduces the 'double marginalisation' problem, to lead to an increase in IOTs. Indeed, if visited operators were to take the retail mark-up as given, a smaller mark-up would tend to increase IOTs. However, as visited networks anticipate the response of mark-ups to a change in IOTs, the optimal IOT is unaffected by competition at the retail level.

Impact of retail competition on quantities and profits

We can establish the impact of competition by differentiating the optimal values for mark-ups, prices, quantities and profits with respect to . The impact on mark-ups is given by:

$$\frac{\partial m_i}{\partial g} = -\frac{e(A - ec)}{(2A + ec)(2e + g)^2}$$

This is negative as long as $A > ec$, i.e. there is positive demand for roaming at marginal cost prices. As expected, retail mark-ups fall, which at unchanged IOTs implies falling retail prices. Demand for roaming services increases as a result. The impact on profits is as follows:

$$\frac{\partial p^{r}{}_{i}}{\partial g} = -\frac{\left(A-ec\right)^{2} g}{9\left(2e+g\right)^{3}}$$

$$\frac{\partial p^{w}{}_{i}}{\partial g} = \frac{2\left(A-ec\right)^{2}}{9\left(2e+g\right)^{2}}$$

This shows that retail operators' profits fall, but wholesale profits increase. Wholesale operators benefit from a more competitive retail market, as the mark-up on their IOTs falls.

In summary, the effects of competition are:

- to lower retail mark-ups on IOTs;
- to reduce the retail price of roaming hence boosting demand; and thus
- to reduce the profits of retail operators whilst increasing profits of wholesale operators.

3.2.2 Asymmetric market shares

Differences in coverage and signal strength might cause the default market shares to differ across visited networks so that $\alpha_i \neq ½$. Where α_i is determined by coverage and signal strength of the visited network (rather than any attempt by the home operator to direct traffic onto a particular visited network), it is the same for all home operators, i.e. $\alpha_1 = \alpha_2$.

The demand faced by retail operators is:

$$d_i = A - b \cdot \left(a w_1 + \left(1-a\right) w_2\right) \cdot (1+m_i) + g \cdot \left(a w_1 + \left(1-a\right) w_2\right) \cdot (1+m_j)\text{, } i \quad j$$

with demand for wholesale services being:

$$d^{w}{}_{1} = a\left(d_1 + d_2\right)$$

$$d^{w}{}_{2} = (1-a)\left(d_1 + d_2\right)$$

2nd stage – home operators set retail mark-ups

Each operator sets mark-ups in order to maximise its retail profit:

$$p^{r}{}_{i} = \left(A - b\left(1+m_i\right)\left(a w_1 + \left(1-a\right) w_2\right) + g\left(1+m_j\right)\left(a w_1 + \left(1-a\right) w_2\right)\right) \cdot m_i \cdot \left(a w_1 + \left(1-a\right) w_2\right)$$

Solving the corresponding first order conditions for the optimal mark-ups we obtain:

$$m_i = m^{*} = \frac{A - e\left(a w_1 + \left(1-a\right) w_2\right)}{\left(2e+g\right)\left(a w_1 + \left(1-a\right) w_2\right)}$$

which again are decreasing in .

1st stage – visited operators set IOTs

Profits by wholesale operators are now:

$$p^{w}{}_{1} = a\left(A + \frac{(g-b)}{2}\left(a\,w_1 + (1-a)\,w_2\right)\left((1+m_1)+(1+m_2)\right)\right)\cdot(w_1 - c)$$

$$p^{w}{}_{2} = a\left(A + \frac{(g-b)}{2}\left(a\,w_1 + (1-a)\,w_2\right)\left((1+m_1)+(1+m_2)\right)\right)\cdot(w_2 - c)$$

Substituting the home operators' optimal mark-ups and solving for the optimal IOTs we obtain:

$$w^{*}{}_{1} = \frac{A + (3a - 1)ec}{3ae}$$

$$w^{*}{}_{2} = \frac{A + \left(3(1-a)-1\right)ec}{3(1-a)e}$$

Whilst the average weighted IOT is the same as in the case where both operators attract half of the roaming traffic, individual IOTs are different. Differentiating by share of roaming traffic s_i where $s_1 = \alpha$ and $s_2 = 1-\alpha$ we obtain:

$$\frac{\partial w_i}{\partial s_i} = -\frac{A - ce}{3 s_i^2 e} < 0.$$

Thus the operator with a higher market share sets a lower IOT. This again is due to the externalities that exist because roaming demand is based on average prices: the smaller the share of roaming traffic attracted by any operator, the smaller the impact of its IOT on the average weighted roaming tariff. Operators with a lower share of traffic therefore have a stronger incentive to increase their IOTs. Average retail prices, demand and profits remain unchanged.

3.3 Cross-border merger

Cross-border mergers have often been perceived as a solution to high roaming charges. The presumption is that vertical integration creates incentives to reduce roaming charges as both the benefits enjoyed by the home operator and the visited network would be taken into account when deciding on IOTs and retail prices.

However, the problem underlying high roaming charges is not the 'double marginalisation' that would be eliminated through vertical integration. Rather, the root cause of high roaming charges is the existence of externalities between visited networks. Indeed, as we show, vertical integration is not in itself a solution to the problem of high roaming charges as long as the basic technological constraints remain.

In the following analysis, we assume that home operator 1 and visited network 1 merge to form an integrated operator. The merged firm now maximises joint profit instead of retail profit and wholesale profit separately.

As before, we assume that demand for roaming services at marginal cost prices is positive, i.e. $A > e \cdot c$.

2nd stage – home operators set retail mark-ups

Profits for the merged operator are:

$$p_1 = d_1 \cdot \left((1+m_1) w_1 - c \right) + d_{12} \cdot m_1 \cdot w_2 + d_{21} \cdot (w_1 - c)$$

For the independent operator retail profits remain unchanged.

The first order conditions for profit maximising mark-ups, are as follows:

$$\frac{\partial p_1}{\partial m_1} = (w_1 + w_2) \cdot \left(2A + ec - g\,(2m_1 - m_2)(w_1 + w_2) - e\left(2(1+m_1)w_1 + m_2 + 2m_1 w_2\right) \right) = 0$$

$$\frac{\partial p_2}{\partial m_2} = (w_1 + w_2) \cdot \left(2A - \left(e - gm_1 + 2(e+g)m_2\right)(w_1 + w_2) \right) = 0$$

This gives optimal mark-ups as:

$$m_1^* = \frac{A(4e+6g) + e\left(2c(e+g) - (4e+5g)w_1 - (2e+3g)w_2\right)}{(2e+g)(2e+3g)(w_1+w_2)}$$

$$m_2^* = \frac{A(4e+6g) + e\left(g\,(c-w_1) - (2e+3g)(w_1+w_2)\right)}{(2e+g)(2e+3g)(w_1+w_2)}$$

1st stage – visited operators set IOTs

Substituting optimal mark-ups in the profit functions of the independent wholesale and the merged operator and solving for optimal IOTs we obtain:

$$w_1^* = \frac{4A(e+g)(2e+3g)\left(4e^2+6eg+3g^2\right) + ce\left(24e^4+88e^3g+128e^2g^2+83eg^3+18g^4\right)}{e\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)}$$

$$w_2^* = \frac{2A(2e+g)\left(12e^3+38e^2g+43eg^2+18g^3\right) + ce(e+2g)(2e+3g)\left(4e^2+6eg+3g^2\right)}{\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)}$$

The merged and the independent wholesale operator set different IOTs. The difference between the IOTs of the merged and the independent wholesale operator is

$$w_1^* - w_2^* = -\frac{2(A-ec)(8e^3+24e^2g+28eg^2+13g^3)}{56e^4+216e^3g+320e^2g^2+215eg^3+54g^4} < 0$$

i.e. the independent operator sets a higher IOT than the merged operator.

Looking at the impact of the merger on the IOT set by each wholesale operator relative to the case where all operators are unrelated, we obtain:

$$w_1^{merger} - w_1^{unrelated} = -\frac{2(A-ec)\left(8e^3+24e^2g+32eg^2+17g^3\right)}{3\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)}$$

$$w_2^{merger} - w_2^{unrelated} = \frac{4(A-ec)\left(8e^3+24e^2g+26eg^2+11g^3\right)}{3\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)}$$

The merged operator, maximising joint profits, lowers IOTs, but the independent operator increases its IOT in response, exploiting the additional headroom created by the merged entity's lower IOTs. Indeed, the average IOT increases as a result of the merger:

$$\frac{w_1^{merger} + w_2^{merger}}{2} - w^{*\ unrelated} = \frac{(A - ec)(2e + g)(4e^2 + 10eg + 5g^2)}{3(56e^4 + 216e^3 g + 320e^2 g^2 + 215eg^3 + 54g^4)} > 0$$

This indicates that the increase in the IOT set by the independent operator is larger than the IOT reduction of the merged firm. Differentiating the difference between the independent firm's IOT and the merged firm's IOT and the difference between the average IOT in the merged case and the case where all operators are independent with respect to γ, it can be shown that the overall impact of the merger is smaller the more intense retail competition between the two home operators. (These derivatives are reported in the appendix.)

Impact on retail prices and profits

Looking at the impact on retail prices, we obtain:

$$P_1^{merged} - P_1^{unrelated} = -\frac{(A - ce)(e + g)(40e^3 + 96e^2 g + 88eg^2 + 31g^3)}{3(2e + g)(56e^4 + 216e^3 g + 320e^2 g^2 + 215eg^3 + 54g^4)}$$

$$P_2^{merged} - P_2^{unrelated} = \frac{(A - ce)(e + g)(8e^3 - 16eg^2 - 13g^3)}{3(2e + g)(56e^4 + 216e^3 g + 320e^2 g^2 + 215eg^3 + 54g^4)}$$

The average retail price charged by the merged entity decreases. The average retail price charged by the independent firm increases if competition in the retail market is weak, but decreases if competition is sufficiently intense.[21] Differentiating with respect to γ it is again easy to show that the impact of a merger on retail prices is smaller the more intense competition in the retail market.

Finally, we can examine the impact of the merger on profits. Lower retail prices and IOTs imply that the merged firm's profits fall relative to the aggregate profit of the previously independent retail and wholesale operator. Profits earned by the independent wholesale operator increase. The profit impact on the independent retailer is dominated by the increase in input costs (as average IOTs go up), which cannot be fully passed on. Although its retail prices increase, the independent retailer's profits fall. (For a proof see the appendix.)

Thus, a cross-border merger appears to be unprofitable, unless it is accompanied by some ability to change the distribution of and increase the share of roaming traffic carried on the merged entity's network. The main reason for this is again the externality that exists between visited networks – the independent wholesale

[21] The sign of $P_2^{merged} - P_2^{unrelated}$ is determined by the sign of

$$(8e^3 - 16eg^2 - 13g^3)\ ,$$

which is negative for   > 0.58ε.

operator has an incentive to free-ride on the attempts by the merged entity to reduce IOTs (and thus retail prices) of roaming services from their excessive levels.

This result remains unchanged if we allow the merged firm to charge different mark-ups for roaming on different networks as long as the market shares of visited networks are unaffected by the difference in retail roaming tariffs.[22] Thus, a natural next step is to examine whether traffic redirection in response to price differences will change our results.

3.4 Incentives for manual network selection

In this section we analyse the implication of manual network selection by assuming that customers are sufficiently aware of and sensitive to price differences to ensure that they manually select the cheapest visited network when roaming. In practice, this is likely to require fundamental changes in the structure of retail roaming offerings to improve price transparency. For example, the Eurocall plan recently launched by Vodafone achieves this by offering a flat retail price for roaming across different countries, differentiated only by whether the visited network is part of the Eurocall group (in which case a special rate applies) or an independent network operator (in which case a higher basic rate is charged).

We assume that the merged entity offers a simplified tariff plan. More specifically, the subscribers of home operator 1 face a different retail price for roaming on visited network 1 – the special tariff – and a basic rate for roaming on visited network 2. We assume that the difference between the special and the basic rate is sufficient to ensure subscribers of home operator 1 will have an incentive always to connect to visited network 1 rather than network 2, thus enjoying the benefits of the lower special tariff.[23] Assuming that the difference between special and basic rate is sufficiently large, and customers are sufficiently price sensitive, we obtain the following shares of roaming traffic generated by subscribers of home operator 1:

$$s_{11} = 1$$
$$s_{12} = 0$$

The corresponding expenditure function is given by $P_1 = p_{1,1}$.

Thus:

$$d_{11} = d_1 = A - b\,p_{11} + g\,P_2$$
$$d_{12} = 0$$

[22] In this case, setting different mark-ups in our simple model is in fact equivalent to setting an absolute retail price for roaming services that would apply to roaming services on any visited network. This absolute retail price would be identical to the average price that emerges from setting uniform mark-ups on different IOTs – the level of demand and profits are unaffected by this, and so are IOTs.

We assume that the demand faced by the independent retail operator remains unchanged and is given by:

$$d_2 = A - b\, P_2 + g\, p_{11}$$

This is split between the two visited networks in line with the default shares (i.e. ½ in our case). As before, we assume that demand for roaming services at marginal cost prices is positive (i.e. $A > e \cdot c$).

2nd stage – independent home operator set retail mark-ups and merged operator sets retail prices

We assume that all roaming traffic generated by subscribers of the merged entity is carried on the merged entities visited network (provided that $p_{12} > p_{11}$). We solve for p_{11} and assume that the merged operator sets p_{12} at a level sufficient to guarantee that its customers will manually select its own network when roaming. This is of course a simplification as in practice operators will have to allow for the possibility that their subscribers roam onto an independent network (e.g. when out of coverage of the network operated by the merged entity). In this case, $p_{1,2}$ cannot be set arbitrarily large to incentivise subscribers manually to select visited network 1, but may be limited by competition between operators: it is essentially the cost of insuring against being out of coverage when taking advantage of the simplified tariff plan.

The first order conditions for profit maximising mark-ups, are as follows:

$$\frac{\partial p_1}{\partial p_{11}} = A + \frac{2e+g}{2} c - 2(e+g)\, p_{11} + \frac{g\,(1+m_2)(w_1+w_2) + g\, w_1}{2} = 0$$

$$\frac{\partial p_2}{\partial m_2} = \left(A - \frac{w_1+w_2}{2}\left(e\,(1+2m_2) + g\,(1+2m_2-2\,p_{11}) \right) \right) \frac{w_1+w_2}{2} = 0$$

This gives optimal retail price for the merged firm and mark-up for the independent firm as:

$$p_{11}^{*} = \frac{A(4e+6g) + (e+g)\left(2c(2e+g) + g\,(3w_1+w_2)\right)}{8e^2 + 16eg + 6g^2}$$

$$m_2^{*} = \frac{A(4e+6g) + cg\,(2e+g) - 2e\,(e+2g)\, w_1 - \left(2e^2 + 4eg + g^2\right) w_2}{(2e+g)(2e+3g)(w_1+w_2)}$$

1st stage – visited operators set IOTs

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[23] In practice, this may not be possible if visited network 1 does not offer full coverage in the roaming country and customers may therefore be required to connect to network 2 in order to avoid black spots.

Substituting the optimal price of the merged firm and the optimal mark-up set by the independent firm in the profit functions of the independent wholesale and the merged operator and solving for optimal IOTs we obtain:

$$w_1^* = \frac{Ag + ce^2}{e(e+g)} + \frac{4(A-ce)(e+g)(2e^2+4eg+g^2)}{12e^4+48e^3g+70e^2g^2+44eg^3+9g^4}$$

$$w_2^* = \frac{A+cg}{e+g} - \frac{4(A-ce)(e+g)(e+2g)e}{12e^4+48e^3g+70e^2g^2+44eg^3+9g^4}$$

Again, the IOTs differ, but unlike in the case of a merger without an incentive for traffic redirection the merged operator sets a <u>higher</u> IOT than the independent operator as long as there is competition in the home market:

$$w_1^* - w_2^* = \frac{g(A-ec)(2e+3g)(6e^3+12e^2g+11eg^2+3g^3)}{e(e+g)(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4)} > 0$$

The explanation for this effect is that the merged entity, by increasing its IOT, can raise its rival's costs at the retail level. Whilst for the merged entity an inflated IOT is simply an internal transfer, the independent retailer faces this as a true cost.[24]

On the other hand, the independent wholesale operator has an incentive to lower the cost faced by the independent retail operator in order to allow for lower retail prices and increase its demand.

This explanation is further confirmed by differentiating the difference in IOTs with respect to : the more intense competition at the retail level, the larger the difference in IOTs. (The derivative can be found in the appendix.)

Comparing the IOTs with respect to the case of independent operators without traffic redirection we obtain:

$$w_1^{merger} - w_1^{unrelated} = \frac{g(A-ec)(12e^4+40e^3g+54e^2g^2+38eg^3+9g^4)}{3e(e+g)(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4)} > 0$$

$$w_2^{merger} - w_2^{unrelated} = -\frac{g(A-ec)(24e^4+86e^3g+120e^2g^2+79eg^3+18g^4)}{3e(e+g)(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4)} < 0$$

IOTs do not change for = 0, confirming that the incentive for setting different IOTs is entirely due to the impact on competition at the retail level where the merged operator has an incentive to raise the costs of its independent rival.

The IOT set by the independent wholesale operator is lower. In the absence of traffic redirection the independent wholesale operator was unaffected by the distribution of roaming traffic between home networks, as it received traffic from both retail operators. However, when the independent visited network only

[24] For a general discussion of these strategies see Salop, S C and Scheffmann, D T, 1987, "Cost Raising Strategies", *Journal of Industrial Economics*, Vol. 36.

receives traffic from the independent home operator, competition in the home market has a direct impact on the demand it faces.

The effective wholesale tariff paid by the independent retail operator is the average IOT, which is lower overall than in the base case. The difference in average IOTs is given by:

$$\frac{w_1^{merger} + w_2^{merger}}{2} - w^{*\ unrelated} = -\frac{g\left(A-ec\right)\left(2e+g\right)\left(6e^2+14eg+9g^2\right)}{6e\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)} < 0$$

The impact on individual and average IOTs is increasing with competition in the home market – the more competitive the home market, the more can be gained by raising rival's costs. The derivatives of changes in individual and average IOTs with respect to are reported in the appendix.

Impact on retail prices and profits

Looking at the impact on retail prices, we find that the merger always creates incentives to reduce the retail price set by the merged entity. By contrast, the independent retail operator only reduces its retail price if there is competition in the home market:

$$P_1^{merged} - P_1^{unrelated} = -\frac{\left(A-ce\right)\left(48e^5+192e^4g+298e^3g^2+228e^2g^3+77eg^4+9g^5\right)}{6e\left(2e+g\right)\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)}$$

$$P_2^{merged} - P_2^{unrelated} = -\frac{g\left(A-ce\right)\left(36e^5+148e^4g+238e^3g^2+188e^2g^3+68eg^4+9g^5\right)}{6e\left(e+g\right)\left(2e+g\right)\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)}$$

The merged operator sets a lower retail price than the independent retailer in all cases:

$$P_1^{merged} - P_2^{merged} = -\frac{\left(A-ce\right)\left(8e^4+30e^3g+42e^2g^2+27eg^3+6g^4\right)}{2\left(e+g\right)\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)}$$

Looking at how the impact of changes is affected by the intensity of competition at the retail level (these derivatives can be found in the appendix), we find that:

- the reduction in retail prices set by the independent retail operator is larger the more intense competition is at the retail level;
- the gap between the two operators' retail prices becomes smaller the more intense competition;
- the reduction in the merged entity's retail price is smaller the more intense competition (reflecting the fact that the double-mark-up that the merged entity is avoiding is smaller the more intense competition at the retail level).

The fall in retail prices leads to an increase in retail demand, which is larger for the merged entity (as it sets a lower price). However, the increase in demand from subscribers of the independent retailer is insufficient to make up for the loss of traffic from the merged entity faced by the independent wholesale operator, and as a result this operator carries less traffic:

$$d^{w_2}{}^{merged} - d^{w_2}{}^{merged} = -\frac{(A - ce)\left(24e^5 + 132e^4g + 280e^3g^2 + 288e^2g^3 + 146eg^4 + 27g^5\right)}{12(2e+g)\left(12e^4 + 48e^3g + 70e^2g^2 + 44eg^3 + 9g^4\right)}$$

If we examine the impact on profits, we can see that the merger is in this case profitable, whilst both independent operators earn lower profits. Again, this effect is stronger the more intense competition is in the home market. (The impact on profits can be found in the appendix.)

Hence, when a merged operator can incentivise its subscribers to select the merged visited network, the merger is profitable. The merged entity benefits from both:

- an increase in traffic on its network from its own subscribers to the detriment of the independent wholesale operator;
- an increase in the margin from wholesale activities, provided there is competition at the retail level and the independent visited network has an incentive to lower IOTs in order to maintain a certain level of traffic from the independent retailer on its network.

The merger is more profitable the more competitive the retail market as differences in retail prices have greater impact on retail demands.

3.5 SIM-based traffic redirection

We have identified muted *price* competition as the main cause for high roaming charges: with network selection being largely left to chance, a single operator reducing its IOT does not enjoy an advantage in terms of attracting a larger share of roaming traffic. As the results of the previous section suggest, if it is possible to establish a link between an operator's IOT and the proportion of roaming traffic attracted to its network, competition between visited networks could shift onto prices and the costs of roaming should decline.

In addition to providing incentives for manual traffic redirection (as in the previous section), home operators would benefit from directing traffic onto visited networks depending on the relative IOTs. In the past, this would have only been possible in a very limited manner, namely by having visited networks compete for exclusive roaming contracts. However, for a variety of reasons (discussed above) such a solution is not very attractive. Technological changes that allow operators to adjust the proportion of traffic handled on different visited networks dynamically promise to change this.

In this section we consider the effect of home operators being able to redirect roaming traffic to visited networks in response to differences in IOTs. This may be possible, for example, with new SIM cards that allow home operators to choose the visited network to which roaming subscribers connect by default through over-the-air programming.

We model SIM-based traffic redirection by allowing home operators to change the default market shares (α) to each visited network, e.g. through SIM-over-the-air programming. Roaming customers do not substantially change these default market shares through manual network selection.

Home operators will attempt to direct traffic to the cheapest visited network. If operators were able to direct all of the traffic generated by their subscribers to the network of their choice, we would have a case of pure undifferentiated Bertrand competition between visited networks, where the visited network offering the cheapest IOT supplies all roaming services. Wholesale operators would set IOTs at marginal cost and share the market. The retail market would then be reduced to a model of Bertrand competition with heterogeneous products, with cost of providing retail roaming services being equal to the wholesale marginal cost of roaming.

However, in practice it may not be possible to direct all traffic to one visited network for a number of reasons such as differences in coverage or roaming subscribers with old SIM cards that do not support traffic redirection. In this case, visited networks would be in imperfect Bertrand competition, with the operator setting the higher IOT still receiving a share of roaming traffic.

We assume that each visited operator *i* directs the roaming traffic generated by its subscribers to visited networks in response to relative IOTs. More specifically, we assume that the share of traffic carried on visited network 1 is given by:[25]

$$a_i\left(w_1, w_2\right) = \frac{w_2}{w_1 + w_2}$$

We further assume $_1$ = $_2$ = (e.g. because both home operators use the same technology for SIM-based traffic redirection). The shares of roaming traffic carried on each of the visited networks are:

$$s_{i1} = a\left(w_1, w_2\right) = \frac{w_2}{w_1 + w_2}$$
$$s_{i2} = 1 - a\left(w_1, w_2\right) = \frac{w_1}{w_1 + w_2} \qquad \text{for } i = 1,2.$$

The corresponding average prices faced by consumers are:

$$P_i = a\, p_{i1} + \left(1 - a\right) p_{i2} = \frac{p_{i2} w_1 + p_{i1} w_2}{w_1 + w_2} \qquad \text{for } i = 1,2.$$

If home operators set retail mark-ups $_i$, this can then be rewritten as:

[25] This function satisfies the following conditions:

$a_i\left(w_1, w_2\right) = \frac{1}{2}$, if $\frac{w_1}{w_2} = 1$;

$a_i\left(w_1, w_2\right) \to 1$, if $\frac{w_1}{w_2} \to 0$;

$a_i\left(w_1, w_2\right) \to 0$, if $\frac{w_1}{w_2} \to \infty$;

$a_i\left(w_1, w_2\right) = 1 - a_i\left(w_1', w_2'\right)$, if $\frac{w_1}{w_2} = \frac{w_2'}{w_1'}$.

$$P_i = 2(1+m_i)\frac{w_1 \cdot w_2}{w_1 + w_2} \quad \text{for } i = 1,2.$$

Thus, retail demand can be expressed as:

$$d_1 = A - 2\frac{w_1 \cdot w_2}{w_1 + w_2}\left(b\,(1+m_1) - g\,(1+m_2)\right)$$

$$d_2 = A - 2\frac{w_1 \cdot w_2}{w_1 + w_2}\left(b\,(1+m_2) - g\,(1+m_1)\right)$$

and wholesale demand will be:

$$d^{w}{}_1 = d_{11} + d_{21} = s_1\left(d_1 + d_2\right) = \frac{1}{1+\frac{w_1}{w_2}}\left(2A - 2\frac{w_1 \cdot w_2}{w_1 + w_2}(b-g)(2+m_1+m_2)\right)$$

$$d^{w}{}_2 = d_{12} + d_{22} = s_2\left(d_1 + d_2\right) = \frac{1}{1+\frac{w_2}{w_1}}\left(2A - 2\frac{w_1 \cdot w_2}{w_1 + w_2}(b-g)(2+m_1+m_2)\right)$$

We assume that demand for roaming services at marginal cost prices is positive (i.e. $A > e \cdot c$), and that operators maximise their respective profits.

2nd stage – home operators set retail mark-ups

Solving for profit maximising mark-ups, we obtain:

$$m_i^* = m^* = \frac{2(e+g)w_1 w_2 + A(w_1 + w_2)}{(2e+g)(w_1 + w_2 + 2w_1 w_2)}$$

1st stage – visited operators set IOTs

Substituting optimal mark-up set by the home operators in the profit functions of the wholesale operators we obtain the corresponding first order conditions:

$$\frac{\partial p^{w}{}_1}{\partial w_1} = \frac{w_2 2(e+g)\left(A(w_1+w_2)(c+w_2) + 2e\,w_2\left(-2w_1 w_2 + c(w_2 - w_1)\right)\right)}{(2e+g)(w_1+w_2)^3} = 0$$

$$\frac{\partial p^{w}{}_2}{\partial w_2} = \frac{w_1 2(e+g)\left(A(w_1+w_2)(c+w_1) + 2e\,w_1\left(-2w_1 w_2 + c(w_1 - w_2)\right)\right)}{(2e+g)(w_1+w_2)^3} = 0$$

which solving for optimal IOTs yields[26]:

[26] Solving for the FOCs gives multiple solutions, but there is a unique maximum for economically significant values of A, c, ε and , as is evident from examining second order conditions.

$$w_i^* = w^* = \frac{A + \sqrt{A}\sqrt{A + 8ce}}{4e}$$

Again, the optimal IOTs do not depend on the level of competition at the retail level but only on market size, marginal cost of providing wholesale services and market retail price sensitivity.

The difference between these IOTs and the profit maximising IOTs in the base case (with or without competition at the retail level) is:

$$w^{*SIMredirection} - w^{*noredirection} = -\frac{5A + 4ce - 3\sqrt{A}\sqrt{A + 8ce}}{12e}$$

This difference is negative[27] for all economically relevant values of *A*, *c* and ε, indicating that, as expected, wholesale charges fall in response to operator-driven traffic redirection. With the introduction of SIM-based traffic redirection, wholesale operators have an incentive to compete for roaming market share by cutting IOTs.

Impact on retail prices

The impact on retail prices compared to the case without redirection is:

$$p_{ij}^{*SIM\ redirection} - p_{ij}^{*noredirection} = -\frac{5A + 4ce - 3\sqrt{A}\sqrt{A + 8ce}}{12e\left(2e + g\right)}\left(e + g\right)$$

This is also negative[28] for all economically relevant values of *A*, *c* and ε, indicating that the IOT reduction is passed through to retail prices. Obviously, the extent of pass-through depends on the level of at the retail level ( ). The partial derivative of the difference in retail prices with respect to is negative[29] for all economically relevant values of *A*, *c* and ε, implying a stronger reduction in retail prices the stronger competition at the retail level.

Retail firms will benefit from the reduction in IOTs as the cost of roaming wholesale services is reduced. However, changes in profits of wholesale firms will depend on how much competition at the wholesale level reduces IOTs. Clearly, in the case of perfect Bertrand competition, all profits are removed from the wholesale operators. However, it may well be possible that wholesale operators benefit from some price competition at the wholesale level to the extent that resulting IOTs are brought closer to the jointly profit maximising level (counter-acting the externality that results in higher-than-optimal IOTs).

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[27] The sign of this difference is defined by the sign of the numerator, which is negative for $A > ec$. A proof can be found in the appendix.

[28] For a proof see the appendix.

[29] For a proof see the appendix.

4 Conclusions

As we have seen, it may be technical constraints on roaming that dampen the price effect on demand and limit competitive pressure on roaming charges.

Cross-border mergers cannot correct this situation and are not profitable unless they are accompanied by some form of traffic redirection. Consumer driven traffic redirection based on manual network selection may be implemented relatively easily by merged entities, albeit at the cost of having a simpler tariff structure and perhaps not being able to discriminate by country.

Technological solutions for traffic redirection are currently very limited, but this might change soon. For example, the SIM application toolkit and over-the-air programming will increase the ability of operators to redirect roaming traffic generated by their subscribers to specific networks.

Such SIM-based traffic redirection will introduce price competition between visited networks. It may further support the increasing use of simplified retail charges as home operators have more control over their input cost in providing retail roaming services. This would further increase the role of roaming charges in competition at the retail level.

Appendix

Impact of competition at the retail level on IOTs in the case of a cross-border merger

Below we present the derivatives of IOT differences with respect to γ referred to in section **Error! Reference source not found.**).

$$\frac{\partial\left(w_1^{merger}-w_1^{unrelated}\right)}{\partial g}=\frac{4\left(A-ec\right)\left(64e^6+256e^5g+512e^4g^2+784e^3g^3+888e^2g^4+576eg^5+153g^6\right)}{\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)^2}>0$$

$$\frac{\partial\left(w_2^{merger}-w_2^{unrelated}\right)}{\partial g}=-\frac{8\left(A-ec\right)\left(e+g\right)\left(64e^5+304e^4g+592e^3g^2+624e^2g^3+369eg^4+99g^5\right)}{\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)^2}<0$$

$$\frac{\partial\left(w_1^{merger}-w_2^{merger}\right)}{\partial g}=\frac{4\left(A-ec\right)\left(192e^6+992e^5g+2304e^4g^2+3216e^3g^3+2874e^2g^4+1512eg^5+351g^6\right)}{\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)^2}>0$$

$$\frac{\partial\left(\frac{w_1^{merger}-w_2^{merger}}{2}-w^{*unrelated}\right)}{\partial g}=-\frac{2\left(A-ec\right)\left(64e^6+480e^5g+1280e^4g^2+1648e^3g^3+1098e^2g^4+360eg^5+45g^6\right)}{\left(56e^4+216e^3g+320e^2g^2+215eg^3+54g^4\right)^2}<0$$

Profit impact of a cross-border merger

Below we present the differences in profits between the merged and the independent entity and the profit difference relative to the base case referred to in section **Error! Reference source not found.**.

$$p_1^{merged} - \left(p^{w\,unrelated}_1 + p^{r\,unrelated}_1\right) = \frac{(A-ce)^2 \left(-\frac{e(e+g)\left(1856e^8 + 12032e^7g + 35200e^6g^2 + 61328e^5g^3 + 70128e^4g^4 + 54000e^3g^5 + 27201e^2g^6 + 8102eg^7 + 1080g^8\right)}{(2e+g)^2\left(56e^4 + 216e^3g + 320e^2g^2 + 215eg^3 + 54g^4\right)^2} \right)}{9e}$$

$$p^{w\,merged}_2 - p^{w\,unrelated}_2 = \frac{16(A-ce)^2(e+g)\left(8e^3 + 24e^2g + 26eg^2 + 11g^3\right)\left(32e^4 + 120e^3g + 173e^2g^2 + 113eg^3 + 27g^4\right)}{9(2e+g)\left(56e^4 + 216e^3g + 320e^2g^2 + 215eg^3 + 54g^4\right)^2}$$

$$p^{r\,merged}_2 - p^{r\,unrelated}_2 = \frac{1}{9}(A-ce)^2(e+g)\left(-\frac{\left(8e^4 + 48e^3g + 80e^2g^2 + 59eg^3 + 18g^4\right)\left(104e^4 + 384e^3g + 560e^2g^2 + 371eg^3 + 90g^4\right)}{(2e+g)^2\left(56e^4 + 216e^3g + 320e^2g^2 + 215eg^3 + 54g^4\right)^2} \right)$$

Impact of competition at the retail level on IOTs in the case of a cross-border merger with incentives for manual network selection

Below we present the derivatives of IOT differences with respect to γ referred to in section 3.4.

$$\frac{\partial\left(w_1^* - w_2^*\right)}{\partial g} = \frac{2(A-ec)(72e^8 + 504e^7g + 1596e^6g^2 + 3048e^5g^3 + 3854e^4g^4 + 3240e^3g^5 + 1712e^2g^6 + 504eg^7 + 63g^8)}{(e+g)^2\left(12e^4 + 48e^3g + 70e^2g^2 + 44eg^3 + 9g^4\right)^2} > 0$$

$$\frac{\partial\left(w_1^{merger}-w_1^{unrelated}\right)}{\partial g}=\frac{(A-ec)\left(48e^8+320e^7g+976e^6g^2+1856e^5g^3+2428e^4g^4+2152e^3g^5+1192e^2g^6+360eg^7+45g^8\right)}{(e+g)^2\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)^2}>0$$

$$\frac{\partial\left(w_2^{merger}-w_2^{unrelated}\right)}{\partial g}=-\frac{(A-ec)\left(96e^8+688e^7g+2216e^6g^2+4240e^5g^3+5280e^4g^4+4328e^3g^5+2232e^2g^6+648eg^7+81g^8\right)}{(e+g)^2\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)^2}<0$$

$$\frac{\partial\left(\dfrac{w_1^{merger}-w_2^{merger}}{2}-w^{*unrelated}\right)}{\partial g}=-\frac{2(A-ec)(e+g)^2\left(12e^4+44e^3g+62e^2g^2+36eg^3+9g^4\right)}{\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)^2}<0$$

Impact of competition at the retail level on retail prices in the case of a cross-border merger with incentives for manual network selection

Below we present the derivatives of retail price differences with respect to γ referred to in section 3.4.

$$\frac{\partial\left(P_1^{merger}-P_1^{unrelated}\right)}{\partial g}=\frac{(A-ec)\left(576e^8+3744e^7g+10248e^6g^2+15936e^5g^3+16064e^4g^4+11024e^3g^5+4940e^2g^6+1260eg^7+135g^8\right)}{6(2e+g)^2\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)^2}>0$$

$$\frac{\partial\left(P_2^{merger}-P_2^{unrelated}\right)}{\partial g}=-\frac{(A-ec)\left(864e^{10}+7104^9g+26016e^8g^2+55968e^7g^3+78088e^6g^4+73152e^5g^5+45868e^4g^6+18588e^3g^7+4528e^2g^8+576eg^9+27g^{10}\right)}{6(e+g)^2(2e+g)^2\left(12e^4+48e^3g+70e^2g^2+44eg^3+9g^4\right)^2}<0$$

Profit impact of a cross-border merger with incentives for manual network selection

Below we present the differences in profits relative to the base case referred to in section 3.4.

$$p_1^{merged} - \left(p^{w}{}_1^{unrelated} + p^{r}{}_1^{unrelated} \right) = \frac{(A-ce)^2 \left(3456e^{11} + 37440e^{10}g + 180096e^9g^2 + 508752e^8g^3 + 938740e^7g^4 + 1187752e^6g^5 + 1050016e^5g^6 + 646996e^4g^7 + 271525e^3g^8 + 73738e^2g^9 + 11646eg^{10} + 810g^{11}\right)}{36e(e+g)(2e+g)^2\left(12e^4 + 48e^3g + 70e^2g^2 + 44eg^3 + 9g^4\right)^2}$$

$$p^{w}{}_2^{merged} - p^{w}{}_2^{unrelated} = -\frac{(A-ce)^2 \left(576e^{10} + 6624e^9g + 32880e^8g^2 + 93912e^7g^3 + 172184e^6g^4 + 212436e^5g^5 + 178580e^4g^6 + 100650e^3g^7 + 36134e^2g^8 + 7389eg^9 + 648g^{10}\right)}{36e(e+g)(2e+g)\left(12e^4 + 48e^3g + 70e^2g^2 + 44eg^3 + 9g^4\right)^2}$$

$$p^{r}{}_2^{merged} - p^{r}{}_2^{unrelated} = -\frac{(A-ce)^2 \left(576e^9g + 4848e^8g^2 + 18048e^7g^3 + 39184e^6g^4 + 54720e^5g^5 + 50824e^4g^6 + 31200e^3g^7 + 12064e^2g^8 + 2628eg^9 + 243g^{10}\right)}{36e(e+g)(2e+g)^2\left(12e^4 + 48e^3g + 70e^2g^2 + 44eg^3 + 9g^4\right)^2}$$

Impact of SIM-based traffic re-direction on IOTs

Below we analyse whether SIM-based traffic redirection increases or lowers IOTs relative to the base case (this analysis is referred to in section 3.5).

The difference between IOTs in the case of SIM-based traffic redirection and the case with no traffic redirection and competition at the retail level is given by:

$$w^{*SIMredirectoin} - w^{*noredirection} = -\frac{5A + 4ce - 3\sqrt{A}\sqrt{A+8ce}}{12e}$$

The sign of this expression depends on the sign of the numerator,

$$sign\left[w^{*SIMredirectoin} - w^{*noredirection}\right] = sign\left[-\left(5A + 4ce - 3\sqrt{A}\sqrt{A+8ce}\right)\right] = sign\left[NUM\right]$$

We can solve for *NUM* = 0 and obtain:

$$NUM = 0 \Rightarrow A = ce$$

Inspecting $\frac{\partial NUM}{\partial A} = -5 + \frac{3(A+4ce)}{\sqrt{A}\sqrt{A+8ce}} = 0$ for $A = ce$ shows that this is also an extremum and evaluating the second derivative of *NUM* with respect to *A* at $A = ce$ shows that this is a local maximum as

$$\frac{\partial^2 NUM}{\partial A^2}\Big|_{A=ce} = -\frac{48c^2e^2}{A^{3/2}(A+8ce)^{3/2}} < 0 .$$

As the second extremum is found at $A = -9ce$, it is also a global maximum for the subset of economically relevant cases $A > ce$.

Given that $NUM = 0$ at $A = ce$, and that $A = ce$ is a global maximum for NUM^*, then $NUM < 0$ for $A > ce$.

Hence, the difference between IOTs in the case of SIM-based traffic redirection and the case with no traffic redirection and competition at the retail level is negative for all the economically relevant cases.

Impact of SIM-based traffic re-direction on retail prices

Below we present similar analysis to identify the change in retail prices that results from SIM-based traffic redirection (referred to in section 3.5).

The difference between retail prices in the case of SIM-based traffic redirection and the case with no traffic redirection and competition in the home market is given by:

$$p_{ij}^{*SIM\ redirectoin} - p_{ij}^{*noredirection} = -\frac{5A + 4ce - 3\sqrt{A}\sqrt{A+8ce}}{12e(2e+g)}(e+g)$$

The sign of this expression is given by the sign of the numerator,

$$sign\left[p_{ij}^{*SIMredirection} - p_{ij}^{*noredirection} \right] = sign\left[-\left(5A + 4ce - 3\sqrt{A}\sqrt{A+8ce} \right)\left(e + g \right) \right]$$

But for any positive values of ε and ,

$$sign\left[p_{ij}^{*SIMredirection} - p_{ij}^{*noredirection} \right] =$$
$$sign\left[-\left(5A + 4ce - 3\sqrt{A}\sqrt{A+8ce} \right)\left(e + g \right) \right] =$$
$$sign\left[-\left(5A + 4ce - 3\sqrt{A}\sqrt{A+8ce} \right) \right] > 0$$

which is negative for all economically relevant cases as we have shown above.

Now we want to study the partial derivative of the difference in prices with respect to , which is given by:

$$\frac{\partial \left(p_{ij}^{*SIMredirectoin} - p_{ij}^{*noredirection} \right)}{\partial g} = -\frac{5A + 4ce + 3\sqrt{A}\sqrt{A+8ce}}{12e\left(2e + g \right)^2}$$

Again, the sign of this derivative is determined by the sign of the numerator, which is negative for al economically relevant cases.

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