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## Discussion paper

# Empirical evidence on the relationship between mobile termination rates and firms' profit

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# Empirical evidence on the relationship between mobile termination rates and firms' profit\*

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## *Abstract*

The comprehensive theoretical literature on mobile termination rates (MTRs) is inconclusive on how the level of MTRs affects overall consumer charges and firms' profit. In a theoretical model, well suited for econometric implementation, we show that where consumers buy a bundle with included usage, as we now observe in the market, the level of MTRs has no impact on retail prices and firms' profit. We use a panel data set from saturated European markets and find that an identical change in MTRs does not have a significant impact on firms' profit.

JEL codes: C23, L21, L51, L96.

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# 1. Introduction

When a telephony subscriber calls a subscriber on another mobile network, the originating network operator pays a fee per minute to the terminating mobile operator denoted *Mobile Termination Rate (MTR)*. Mobile operators terminate two types of calls – calls originating on another mobile network, Mobile-To-Mobile (MTM) calls, and calls originating on the fixed network, Fixed-To-Mobile (FTM) calls.

In Europe, most operators use a common MTR for both types of calls. The European Commission wants to reduce the level of MTRs, and the authorities' conjecture is that this would benefit consumers by lowering their overall payments.<sup>1</sup> However, the theoretical literature is inconclusive on the effect of changes in MTR levels on overall consumer charges and firms' profit. With regard to FTM calls, the literature on competitive bottlenecks predict that reduced MTRs will result in higher retail charges – the so-called waterbed effect.<sup>2</sup> With regard to MTM calls, a major insight from the two-way access literature is that this depends on the type of retail tariffs offered to consumers.<sup>3</sup>

The empirical literature on the relationship between the level of MTRs and the level of overall retail charges and profits is sparse. Genakos and Valletti (2011a) focus on FTM termination rates and find a significant waterbed effect.<sup>4</sup> Regressions of firms retail charges on their MTRs show that a MTR reduction of 10% leads to 2-15% reduction in retail charges. Using a measure of firm profit (EBITDA<sup>5</sup>) as dependent variable, they find a positive effect of MTRs indicating that the waterbed effect is not 100%. Genakos

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<sup>1</sup> See e.g. the European Commission (2008) and the European Regulatory Group (2007).

<sup>2</sup> See Armstrong (2002, section 3.1) and Wright (2002)

<sup>3</sup> The seminal papers on two-way access by Armstrong (1998) and Laffont, Rey and Tirole (1998a, 1998b) provide a theoretical framework to analyse competition between interconnected networks, including how the level of MTRs affect profit. Armstrong (2002) provides a comprehensive review of the early literature building on the above cited papers. Hoernig (2010) and Armstrong and Wright (2009) synthesize and summarize the subsequent literature on mobile call termination.

<sup>4</sup> Reporting on the results of various regressions of firms retail charges on their MTR, they report that “although regulation reduced termination rates by about 10%, this also led to a 5% increase in mobile retail prices, varying between 2% and 15% depending on the estimate”, Genakos and Valletti (2011a, p. 1116).

<sup>5</sup> *Earnings Before Interests Taxes, Depreciations and Amortisations*.

and Valletti (2011b) document that, in line with theoretical results in the two-way access literature, the waterbed effect is stronger for post-paid subscriptions than for prepaid subscriptions.

Our paper complements the existing empirical literature, described above, in that we depart from a theoretical model of competing, interconnected mobile networks where users make MTM calls.<sup>6</sup> Thus, a mobile operator's profit will depend on its own MTR as well as on all other MTRs in the mobile market.<sup>7</sup> Similar to Genakos and Valletti (2011a) we assume that consumers buy a bundle with included usage.<sup>8</sup> Tariffs with included usage have been commonplace in the US mobile market, and in recent years such tariffs have become common also in Europe. In practice operators offer a menu of different tariffs. The approach to assume that operators compete in total average retail charges is an approximation to capture the average impact from MTRs on profit and it guides the empirical specification. We derive a benchmark closed form equation for the relationship between MTRs and profit, and show that in a saturated market an identical change of the firms' MTRs has no impact on retail prices and firms' profit.

We take a slightly generalized version of this model to a panel dataset comprising 26 mobile operators in 9 saturated European countries in the period 2003-2006. Since MTRs vary significantly both within and between markets in this period, the data set is well suited to test the impact from changes in MTRs on firms' profit. In line with theoretical predictions, we find that an increase in a firm's own MTR will increase profit and an increase in the average MTR of the other mobile firms will decrease profit.

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<sup>6</sup> In our theoretical model we generalize the Hotelling framework based on von Ungern-Sternberg (1991) to an n-firm model well suited for econometric implementation. All European states have more than two operators which are frequently highly asymmetric in terms of market shares and termination rates. To fit key market features we thus allow for competition between n-firms, asymmetric MTRs, differences in marginal costs and vertical differentiation. The "pyramid model" of von Ungern-Sternberg (1991) allows firms to compete directly against each other. For more than three firms the model then differs at this point from the model of Salop (1979). The "spokes model" by Chen and Riordan (2007) provides a closely related approach to allow more than three firms to compete directly against all other firms. Calzada and Valletti (2008) and Jeon and Hurkens (2008) consider models with more than two firms. However, they focus on symmetric firms.

<sup>7</sup> Genakos and Valletti (2011a) depart from a model where MTM-calls are suppressed.

<sup>8</sup> Recent literature within behavioural economics on add-on pricing (Ellison, 2005) and overconfident consumers (Grubb, 2009) provides support for this assumption on retail pricing.

Furthermore, an identical increase in all MTRs in the market has a positive, but insignificant impact on firms' profit.

There exists a comprehensive theoretical literature on the relationship between MTRs and firms' profit. In the case with linear pricing and no discrimination based on whether the call terminates on-net or off-net (Armstrong, 1998, and Laffont, Rey and Tirole, 1998a) an increase in the symmetric MTR increases profits. Thus networks can use a high termination rate as an instrument to soften competition by raising each other's marginal cost.

However, naked linear retail tariffs are rarely observed – even on prepaid subscriptions. A combination of lump-sum fees and usage charges has been considered as a better approximation to observed retail pricing, and Laffont, Rey and Tirole (1998a) demonstrate that the profit raising effect from increasing MTRs disappears when the networks compete in two-part tariffs. Any increase in termination revenues from a higher MTR is passed on to customers in the form of a reduction in the subscription fee - a complete waterbed effect.<sup>9</sup>

Gans and King (2001) show that if firms use two-part tariffs and network based discrimination, i.e. different prices for calls terminated off-net compared to on-net, an increase in the MTRs *decreases* profits.<sup>10</sup> Despite the fact that this may give a good picture of a widely used retail pricing structure, as pointed out by Armstrong and Wright (2009), no regulator has taken seriously the concern that a low level of MTRs may be used as a collusive device.<sup>11</sup>

Armstrong and Wright (2009), provide an explanation for this puzzle building on the fact that mobile operators terminate two types of calls – Mobile-To-Mobile (MTM)

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<sup>9</sup> Dessein (2003) and Hahn (2004) extend this basic model to allow for customer heterogeneity. They find that the profit neutrality result still holds when the networks compete in menus of non-linear tariffs as long as all customer groups participate in equilibrium.

<sup>10</sup> The effects of an increase in the termination rate when the networks compete in pure linear prices with network based discrimination are ambiguous. Laffont, Rey and Tirole (1998b) find that profits increase when the networks are not too close substitutes, while the effect is ambiguous otherwise.

<sup>11</sup> In fact, according to this result bill-and-keep arrangements may be considered as a form of tacit collusion.

calls and Fixed-To-Mobile (FTM) calls. If the firms were free to negotiate a reciprocal MTR for MTM calls and unilaterally set a separate termination rate for FTM calls, they would set the symmetric MTM termination rate below marginal costs and the FTM termination rate above marginal costs. In practice, due to the ability of arbitrage, the firms are constrained to take approximately the same price for MTM as for FTM termination even if regulation does not require uniformity (as is often the case). Thus, if networks are forced to negotiate a uniform MTR for both MTM and FTM calls the level would be a compromise between the two forces. If the market is covered, termination revenues from FTM calls do not affect profit within the model by Armstrong and Wright (2009). In this case the uniform MTR would be the same as if FTM traffic were not present. We show a similar result; FTM traffic does not affect profit when the market is saturated (see Appendix A).<sup>12</sup>

Since we observe a development where the relative FTM volumes are reduced, and markets become more saturated, the predictions from Armstrong and Wright (2009) indicate that the authorities should take the puzzle from Gans and King (2001) more seriously. However, we show that an identical increase in the firms' MTRs has a positive, but insignificant impact on firms' profit (also in saturated European markets). One explanation may be the development in retail pricing where more consumers buy a bundle with included usage.

On the one hand, our results support policy makers' tendency not to worry about the fact that low MTRs may be used as a collusive device. On the other hand, even though we do not have data on retail prices, the results indicate that a reduction in MTR levels will not necessarily benefit consumers.

The rest of the paper is organised as follows: In section 2 we develop the theoretical model of competition between asymmetric networks. In section 3 we describe the data and present the econometric specification. In section 4 we present and discuss the estimation results. Finally, we offer some concluding remarks in section 5.

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<sup>12</sup> If the market is not covered the two forces work such that the larger the FTM share of incoming traffic and the larger the market expansion possibilities, the higher will be the negotiated uniform MTR.

## 2. The theoretical model

Assume that subscribers buy a bundle with included usage. As a normalisation, each subscriber makes exactly one call in the time period under consideration (this normalisation is relaxed in the empirical implementation). Then mobile networks compete for customers in a single price  $p_i$ .<sup>13</sup> Finally, we assume that the market is fully covered i.e.,  $\sum_{i=1}^N x_i = X$ , where  $x_i$  is the number of customers of firm  $i$ ,  $X$  is the total number of potential customers, and the market share of firm  $i$ ,  $s_i = x_i / X$ . These assumptions are basically equal to those in the asymmetric duopoly model in Armstrong (2002).

We assume that there are  $N \geq 2$  interconnected mobile firms in the market and calling patterns are assumed to be uniform. Without loss of generality, we assume zero fixed costs per subscriber and that the marginal cost of originating a call is equal to the marginal cost of terminating a call. These marginal costs may vary between firms, such that, for network  $i$ , an on-net call consists of origination and termination costs,  $2c_i$ . Let  $a_i$  denote the termination rate network  $i$  receives per incoming call. A call from network  $i$  to network  $j$  thus has perceived marginal cost  $c_i + a_j$ , and the (wholesale) margin on an incoming call is  $a_i - c_i$ .

Profit for firm  $i$  is then given by

$$\pi_i = \underbrace{s_i X (p_i - s_i 2c_i - \sum_{j \neq i} s_j (c_i + a_j))}_{\text{Retail profits}} + \underbrace{s_i X \sum_{j \neq i} s_j (a_i - c_i)}_{\text{Wholesale profits}}.$$

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<sup>13</sup> See Genakos and Valletti (2011a). They also assume that the firms offer a bundle of services at a total charge. de Bijl and Peitz (2002) assume that the networks compete in ‘flat-rate’ tariffs, i.e. a subscription fee and a zero charge for calls. A related, very frequently offered tariff is that of ‘included minutes’ – a tariff with a subscription fee, an included number of minutes at a zero charge, followed by a positive marginal charge. This kind of three-part tariff has, to our knowledge, not been analysed in the context of interconnected networks, see Grubb (2009) for a general analysis without interconnection.

Using the fact that market shares sum up to one this profit expression can be simplified to

$$\pi_i = s_i X \left( p_i - 2c_i + \sum_{j \neq i} s_j (a_i - a_j) \right). \quad 1)$$

The market shares entering the profit expression are functions of the vector of prices,  $\mathbf{p} = \{p_1, p_2, \dots, p_N\}$ , and a vector of exogenous firm specific characteristics,  $\mathbf{u} = \{u_1, u_2, \dots, u_N\}$ ,

$$s_i = s(\mathbf{p}, \mathbf{u}), \quad \frac{\partial s_i}{\partial p_i} < 0. \quad 2)$$

The vector  $\mathbf{u}$  allows for vertical differentiation. A firm may have a vertical advantage due to, for instance, brand loyalty or better additional services. Recent analyses (Grajek and Kretschmer, 2009, and Eggers, Grajek and Kretschmer, 2011) suggest that there are significant first mover advantages in mobile markets, and such asymmetries in market shares may then be present also in mature markets. Thus, the model allows for asymmetric market shares even if all prices are equal.

The game proceeds in the usual fashion: In stage 1 the firms' termination rates,  $a_1, a_2, \dots, a_N$  are determined, for instance set by the regulatory authority; in stage 2 the firms set retail prices simultaneously.

If we differentiate (1) with respect to price and rearrange, we can write the first-order condition for firm  $i$ ,  $i = 1, 2, \dots, N$ , as:

$$p_i = 2c_i - \sum_{j \neq i} s_j (a_i - a_j) - s_i \left( \frac{\partial s_i}{\partial p_i} \right)^{-1} \left( 1 + \sum_{j \neq i} \frac{\partial s_j}{\partial p_i} (a_i - a_j) \right). \quad 3)$$

The solution of the  $N$  first-order conditions gives a candidate equilibrium. In general, an interior equilibrium will exist if conditions are not 'too asymmetric', and if the firms' products are not 'too close substitutes'.<sup>14</sup> The interior equilibrium is a price vector

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<sup>14</sup> With "Hotelling style" market share functions, the interior equilibrium is unique, see the next section.



$\mathbf{p}^* = \{p_1^*, p_2^*, \dots, p_N^*\}$  that satisfies the first-order conditions such that  $\sum s_i^* = 1, s_i^* \in \langle 0,1 \rangle$  and  $\pi_i^* \geq 0 \forall i$ . The equilibrium market share of firm  $i$  is given by

$$s_i^* = s_i^*(\mathbf{a}, \mathbf{c}, \mathbf{u}), \quad 4)$$

and equilibrium profit of firm  $i$ ,  $\pi_i^*$ , is obtained by inserting  $\mathbf{p}^*$  and  $\mathbf{s}^*$  in 1). In the following discussion we assume that an interior equilibrium exists.

In the first order conditions, (3), termination rates enter as differences,  $a_i - a_j$ . Consequently, if an interior equilibrium exists, equilibrium prices are identical under  $\mathbf{a} = \{a_1, a_2, \dots, a_N\}$  and  $\tilde{\mathbf{a}} = \{a_1 + d, a_2 + d, \dots, a_N + d\}$  for any  $d$ .

In line with most of the theoretical literature on competition between interconnected networks, the point of departure is product differentiation à la Hotelling. We assume that all consumers subscribe to one and only one firm, and that market shares satisfy:

$$\frac{\partial s_j}{\partial p_i} = \sigma, \text{ all } j \neq i, \sigma > 0 \quad \text{A.1)}$$

$$\frac{\partial s_i}{\partial p_i} = -(N-1)\sigma. \quad \text{A.2)}$$

A.1) and A.2) imply multi-firm competition in the sense that every firm is in direct competition with all other firms. Anderson, de Palma and Thisse (1992) characterize this property as “strong gross substitutes”. A necessary condition for this property to hold is that  $M \geq N - 1$ , where  $M$  is dimensions of an attribute space and  $N$  is the number of competing firms (Anderson, de Palma and Thisse, 1992, p. 115). The parameter  $\sigma$  measures the degree of substitutability between firms.

For  $N = 2$  and  $N = 3$ , A1) and A2) are satisfied in the Hotelling (1929) and the Salop (1979) framework, respectively. For  $N > 3$ , a model that satisfies A1) and A2) is

presented in von Ungern-Sternberg (1991).<sup>15</sup> The spatial interpretation of the von Ungern-Sternberg model is that each firm is located at the corners of an equilateral multidimensional pyramid. Consumers are uniformly distributed on the line segments connecting all corners of the pyramid. The consumers incur travelling costs when consuming services. To save notation we do not allow corners without a firm.<sup>16</sup>

An example of market shares satisfying A.1) and A.2) is the Hotelling style market share function:

$$s_i = \frac{1}{N} + \sigma \left( (N-1)u_i - \sum_{j \neq i} u_j - ((N-1)p_i - \sum_{j \neq i} p_j) \right), \quad 5)$$

where the  $u$ 's are the firm specific characteristics introduced earlier.

We then have the following result:

**Proposition 1:** *If an interior equilibrium exists and the market shares obey (A.1) and (A.2) equilibrium profit is given by*

$$\pi_i^* = X s_i^{*2} \left( \frac{1}{(N-1)\sigma} + a_i - \frac{\sum_{j \neq i} a_j}{N-1} \right) \quad 6)$$

*Proof.* By inserting the rule for optimal pricing (3) using (A.1) and (A.2) into the profit definition 1) we obtain:

$$\pi_i = s_i X \left( \left( 2c_i - \sum_{j \neq i} s_j (a_i - a_j) + \frac{s_i}{\sigma(N-1)} \left( 1 + \sum_{j \neq i} \sigma (a_i - a_j) \right) \right) - 2c_i + s_i \sum_{j \neq i} s_j (a_i - a_j) \right)$$

Rearranging this expression using  $s_i = s_i^*$ , gives equation (6). *Q.E.D.*

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<sup>15</sup> The “spokes model” by Chen and Riordan (2007) is also consistent with A1 and A2.

<sup>16</sup> We are not analysing entry and exit in our model. Thus, disallowing vacant corners does not restrict the analysis.

We show in Appendix A that the result in Proposition 1 also holds if we incorporate a fixed-line network into the model. This is consistent with Armstrong and Wright (2009) who show that if the market is covered, termination revenues from FTM calls do not affect profit.

In accordance with the classical Hotelling duopoly model, equilibrium profit is a function of squared market share. It is easily verified that in symmetric duopoly equation (6) is given by  $\pi_i^* = (s_i^*)^2 / \sigma = 1/4\sigma$ . When market shares are given by equation (5), twice differentiation of (1) shows that the second order condition is  $-(1/(N-1)\sigma + a_i - \bar{a}_{-i}) < 0$ , where  $\bar{a}_{-i} = (N-1)^{-1} \sum_{j \neq i} a_j$ . Hence, the second order conditions restrict the degree of asymmetry in the MTRs. Furthermore, when MTRs satisfy the second order condition, the profit function is globally concave in own-price and an interior equilibrium, if it exists, is unique.

A key feature of equation (6) is that it is separable in equilibrium market share. As will be shown in the next section, this is a very convenient feature for the current econometric purpose. The separability is a consequence of the, admittedly, very restrictive assumptions A1) and A2).<sup>17</sup>

This result may be compared with the profit neutrality result obtained when the networks compete in two-part tariffs with no network based discrimination (Laffont, Rey and Tirole, 1998a, Dessen, 2003, and Hahn, 2004). In general, these authors, and others, are very careful not to overestimate the robustness of the profit neutrality result. In particular the dependence on symmetry is stressed. In these models an identical reduction in MTRs per-minute termination charges decreases per-minute prices but raises the fixed fee (the waterbed effect). In the present model, there is no such waterbed effect since the consumers buy a bundle with included minutes at zero marginal costs. The profit neutrality effect in the present model arises more directly, and

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<sup>17</sup> Alternatively, if the market shares are of the logit type such that:  $\partial s_j / \partial p_i = s_i s_j / \mu$

and  $\partial s_i / \partial p_i = -s_i(1-s_i) / \mu$ , it can be shown that equilibrium profit is given by

$\pi_i^* = X (s_i^*)^2 / (1-s_i^*) \left( \mu / s_i^* + (1-s_i^*) a_i - \sum_{j \neq i} s_j^* a_j \right)$ . We will not pursue this specification here.

in contrast to the abovementioned models the present result is very robust to asymmetric conditions. The result holds even if firms are subject to different MTRs, different marginal costs and vertical differentiation. Given that the assumption on retailing pricing made in the present paper matches the development towards tariffs with included usage, this direct profit neutrality effect may also be empirically important.

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### 3. The econometric model

#### Definitions and descriptive statistics

Data are from Ovum and Wireless Intelligence, and comprise 26 mobile operators in 9 countries located in North-Western Europe<sup>18</sup>. The countries are similar in the sense that they are all high-income countries with a very high mobile penetration. Thus they come close to satisfying the assumptions of full participation underlying the theoretical model. The data set contains quarterly information on key operator indicators, market statistics and termination rates in the period Q1 2003 to Q3 2006, see Table 1 below for further details.

Let subscript  $t$  denote period,  $i$  firm, and  $k$  the national market of firm  $i$ . We ignore international and fixed line traffic (see discussion above). In relation to the current model this implies that the mean of the termination rates on outbound traffic of firm  $i$  is taken over all other mobile operators in firm  $i$ 's national market, i.e.  $\bar{a}_{-it} = 1/(N_k - 1) \sum_{j \neq i} a_{jt}$ . We shall discuss some possible implications of this simplification in the next section. To avoid cumbersome notation it is implicitly assumed that the summation is taken only for operators within each national market  $k \in [1, 2, \dots, K]$ . The number of firms in each national market is not time indexed because there is no operator entry or exit in the markets in the sample period.

Let  $mtr_{it}$  denote the MTR per minute of firm  $i$  in period  $t$ . The theoretical model in the previous section assumed unit demand, i.e. that each customer made exactly one call per period. If we assume that this call has a duration of one minute we have that  $a_{it} = mtr_{it}$

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<sup>18</sup> The countries are Belgium, Denmark, Finland, France, Germany, The Netherlands, Norway, Sweden and The United Kingdom.

for each firm  $i$ . It is now easily verified that if we instead assume that each customer makes, say 30 calls of one minute per period, the profit function would be the same as in (6) with  $a_{it} = mtr_{it}30$ . Following this reasoning we let  $a_{it} = mtr_{it}M_{kt}$ ,  $\forall i \in k \in K$ , where  $M_{kt}$  is the average number of originated mobile minutes per customer in country  $k$  in period  $t$ .<sup>19</sup> As a measure of operator profit we use *EBITDA*. Since there is no investment in the theoretical model, this is the economic performance indicator that comes closest to the profit measure,  $\pi_{it}$ , in equation (6).

Table 1. Descriptive statistics

| <i>Variables</i>   | <i>Explanation</i>   | <i>Mean</i> | <i>Std.dev</i> | <i>Min</i> | <i>Max</i> |
|--------------------|--|-------------|----------------|------------|------------|
| <b>Definitions</b> |  |             |                |            |            |
| $ebitda_{it}$      | Quarterly earnings before interest, taxes, depreciation and amortisation of firm $i$ (in million Euros). | 280.81      | 266.82         | -11.05     | 1007.83    |
| $mtr_{it}$         | Mobile termination rate per minute of firm $i$ in Euros.   | 0.12        | 0.04           | 0.06       | 0.21       |
| $s_{it}$           | Firm $i$ 's market share (of customers)  | 0.30        | 0.14           | 0.08       | 0.58       |
| $M_{kt}$           | Average, quarterly number of mobile minutes in national market $k$                                       | 141.08      | 41.57          | 74.00      | 253.00     |
| $X_{kt}$           | Number of mobile customers, in millions, in market $k$   | 33.87       | 28.28          | 3.47       | 83.12      |
| $N_k$              | Number of mobile network operators in market $k$ . Time invariant in sample.                             | 3.58        | 0.82           | 2          | 5          |
| <b>Dependent</b>   |  |             |                |            |            |
| $y_{it}$           | $ebitda_{it} / X_{kt} s_{it}^2$ .  | 121.88      | 66.68          | -249.00    | 523.02     |
| <b>Explanatory</b> |  |             |                |            |            |
| $a_{it}$           | $mtr_{it} M_{kt}$ .  | 50.64       | 20.77          | 23.83      | 136.18     |
| $\bar{a}_{-it}$    | $1/(N_k - 1) \sum_{j \neq i} mtr_{jt} M_{kt}$ .  | 50.19       | 17.74          | 25.38      | 114.62     |

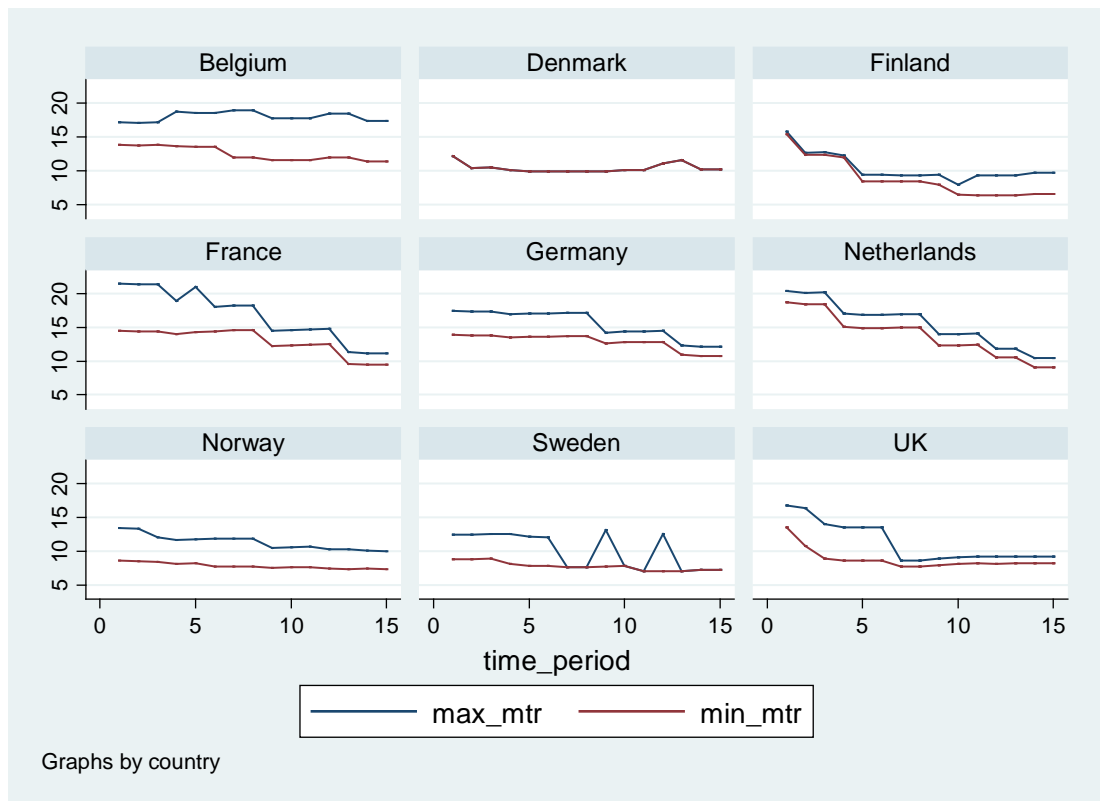
Sources: The mobile termination rates are from Ovum. All other variables are from Wireless Intelligence. The data are from Q1 2003-Q3 2006. The number of observations is 258. This comprises 26 operators in Belgium, Denmark, Finland, France, Germany, The Netherlands, Norway, Sweden and the United Kingdom.

Table 1 reveals that the sample comprises firms and markets of considerable heterogeneity. The smallest market in the sample comprises about 3.5 million customers

<sup>19</sup> Note that this is a slight abuse of notation with respect to the theoretical model since scaling the firm-specific termination rates,  $mtr_{it}$ , with market average volumes,  $M_{kt}$ , gives an imperfect measure of termination revenues, not termination rates. Regression on un-scaled termination rates gives qualitatively the same results as presented in the text (i.e non-rejection of profit neutrality), but the fit is better using the specified scaling.

(Norway in 2003) while the largest, Germany, is well above 80 million in 2006. The smallest firm in the sample (relative to market size) has 8 % of the market, while the largest (again relative to market size) has 58%.

Figure 1 shows the evolution in the MTRs per minute, in Eurocents, of the firms having the highest and the lowest *mtr* in each respective market. As may be seen, Denmark is the only country that has maintained symmetric MTRs throughout the whole period, while Finland and Sweden have periods with symmetric MTRs. In general, there have been frequent changes in both levels and the degree of asymmetry. Hence, the data should be informative with respect to the impact of MTRs on profits.



**Figure 1. MTRs per minute in the period 2003 – 2006.**

### ***The econometric specification***

Having clarified the empirical representation of the variables, we can now present the econometric model. To guide the specification, we use the profit function in (6). If we divide both sides by  $X_{it}s_{it}^2$ , we obtain

$$\frac{\pi_{it}}{X_{it}s_{it}^2} = \frac{1}{\sigma_k(N_k - 1)} + a_{it} - \bar{a}_{-it}.$$

Hence, an econometric specification that nests the theoretical profit function, suitable to the present data, is given by

$$y_{it} = \gamma_i + \beta_1 a_{it} + \beta_2 \bar{a}_{-it} + v_{it}, \quad \forall i, t$$

$$E(v_{it}, v_{it}) = \delta_{it}^2, \quad E(v_{it}, v_{jt}) = \rho_k, \quad (i, j) \in k, \quad E(v_{it}, v_{jt}) = 0 \quad (i \in k \vee j \in l \neq k) \quad 7)$$

where  $y_{it} = \pi_{it} / X_{it}s_{it}^2$ ,  $\gamma_i$  is a firm specific constant and  $v_{it}$  is an error term. As is evident from 7) we allow the errors to be heteroskedastic and correlated within clusters defined by each national market. The former accounts for the large heterogeneity in the sample, and the latter for the fact that the firms may be subject to country-specific, unobservable shocks.<sup>20</sup>

The errors,  $v_{it}$ , are likely to be correlated with the regressors. Even if all operators are subject to some form of ex ante regulation in the market for termination of voice calls, certain operators may have some discretion in setting their own MTR. For instance, some operators may be subject merely to a “fair and reasonable price” obligation, see European Regulatory Group (2007). In particular, regulators often allow late entrants to set a relatively higher MTR than incumbents. The motivation is normally that a

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<sup>20</sup> Correlated error within cross sections in the same country may also be generated by shocks to exchange rates since we measure all monetary variables in Euros and some countries in the sample have their own currency.

unilateral high MTR stimulates post-entry profits and thereby entry.<sup>21</sup> Thus profits and MTRs may to some extent be determined simultaneously.

**Table 2. Correlations**

|            | <i>s</i> | <i>ebitda</i> | <i>ebitda/customer</i> |
|------------|----------|---------------|------------------------|
| <i>mtr</i> | -0.5**   | -0.13*        | -0.35**                |

\*\* p < 0.01, \* p < 0.05

Table 2 shows the correlation between firms' own MTR rate and some firm performance indicators. As is seen, there is a clear tendency that small and/or low-profit operators have a higher MTR. This supports the notion that the model (7) may be subject to simultaneity.

The profit measure, *EBITDA*, will in general contain revenue components that are not incorporated in the theoretical model, for instance roaming and various kinds of data traffic, as well as cost components that are not marginal costs. Thus, we allow for a firm specific constant in (7) although the model outlined in the previous section only requires a country-specific constant.

In general, the structure of the theoretical equilibrium profit function makes the econometric specification very robust to unobservable firm specific effects. The unobservable firm specific effects from the theoretical model, i.e. marginal costs and the differentiation parameters, affect profits through market shares only. Since the profit function is separable in equilibrium market shares, the specification is robust even to time variation in these unobservable variables.

## 4. Empirical results

From the discussion in the previous section it is clear that we need a robust panel estimator that can take account of correlations between cross-sections within clusters (countries) as well as endogeneity. Table 3 below presents the results from GMM

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<sup>21</sup> See e.g. the European Regulatory Group (2006). Carter and Wright (2003) and Peitz (2005a, 2005b) show that a unilateral increase in the MTRs stimulates profits (locally around cost based regulation).



instrumental variable estimation of the econometric model (7).<sup>22</sup> The fixed effects are removed by the within transformation.<sup>23</sup> The table displays two sets of estimates: Models (1)-(2) and models (1a)-(2a). Model 1 is identical to model 1a and so forth except that the latter does not include time dummies. We display both sets of results because, in order to implement the cluster option, the time dummies had to be “partialled out” from the other variables, including excluded instruments, in order to obtain the covariance matrix of orthogonality conditions of full rank (see Baum, Schaffer and Stillman, 2006). This implies that the coefficients of the time dummies cannot be displayed and we cannot perform conventional tests on their impact. We therefore present the effect of including them by displaying both sets of results. Appendix B shows the results of estimating the model without the cluster option.

To identify the parameters in the model we need a set of instrumental variables - that is variables that are a) uncorrelated with the error term and b) correlated with the explanatory variables. The candidate instruments are  $\mathbf{z} = a_{it-1}, \bar{a}_{-it-1}, s_{it-1}, (ebitda / cust)_{it-1}$ . Let us start with correlation with the explanatory variables: The first two variables in  $\mathbf{z}$  will be correlated with the explanatory variables whenever there is some inertia in the MTRs. Inspection of Figure 1 reveals that this is indeed the case. Furthermore, current MTRs may be correlated with the last two variables since the regulators may use firm indicators to determine future MTRs, recall Table 2 and the discussion in the previous section. As shown by the first stage regression in Appendix C, there is no problem with weak instruments. The Shea  $R^2$  from the first stage regressions is in the range of 0.44-0.48.

Why should  $\mathbf{z}$  be valid? Regarding  $a_{it-1}$  and  $\bar{a}_{-it}$  the intuitive argument is that the first lag of the right hand side variables is valid instrumental candidates in the static regression because it is the *current* termination rates that affect profits – lagged

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<sup>22</sup> The results presented in this section are based on a sample where the operators in Denmark have been removed. This is because the Danish operators have been subject to symmetric regulation in every quarter, which causes the regressors to be perfectly correlated for these cross-sections.

<sup>23</sup> The estimation is performed in the module `xtivreg2` for Stata using the GMM robust, cluster option. Prior to estimating the models in Table 3 we ran some regressions with explicit firm dummies and tested for heteroskedasticity. All tests revealed a strong presence of heteroskedasticity.

termination rates do not affect contemporary profits except possibly indirectly via inertia in the pricing decision. The same argument holds for  $s_{it-1}$  and  $(ebitda/cust)_{it-1}$  - past performance should not affect profit in a static model.

Thus, the orthogonality of  $\mathbf{z}$  depends critically on the assumption that the estimated model is in fact static. If the true model is dynamic,  $\mathbf{z}$  will be correlated with the omitted lagged endogenous variable and hence invalid. To test this assumption we estimate a dynamic first differenced model, Arellano and Bond (1991). The results are shown in Appendix D. As can be seen, we cannot reject that the coefficient of the lagged endogenous variable is zero at any conventional level of significance. Finally, we test validity using the Sargan-Hansen test in the overidentified models (2) and (2a). As is evident from Table 3, the Hansen J test does not reject null of valid instruments. The same holds for regressions using further lags of the variables in  $\mathbf{z}$ .<sup>24</sup>

**Table 3. Termination rates and profit: GMM cluster fixed effects<sup>1</sup>**

Model:  $y_{it} = \gamma_i + \beta_1 a_{it} + \beta_2 \bar{a}_{-it} + v_{it}$

|                                 | (1) <sup>2</sup> | (2) <sup>3</sup>  | (1a) <sup>2</sup> | (2a) <sup>3</sup>  |
|---------------------------------|------------------|-------------------|-------------------|--------------------|
| $a_{it}$                        | 1.17**<br>(0.56) | 1.18**<br>(0.53)  | 1.16**<br>(0.50)  | 1.27***<br>(0.44)  |
| $\bar{a}_{-it}$                 | -0.57<br>(0.35)  | -0.70**<br>(0.32) | -0.62*<br>(0.37)  | -0.78***<br>(0.29) |
| Time dummies                    | Yes              | Yes               | No                | No                 |
| R <sup>2</sup>                  | 0.05             | 0.05              | 0.05              | 0.05               |
| Obs                             | 236              | 231               | 236               | 231                |
| Firms                           | 22               | 21                | 22                | 21                 |
| <i>Diagnostics</i> <sup>4</sup> |                  |                   |                   |                    |
| Hansen J                        |                  | 0.56              |                   | 0.62               |
| Endogeneity                     | 0.11             | 0.09              | 0.26              | 0.18               |

Notes:

1) The variables are defined in table 1. Standard errors in parentheses. \*\*\*, \*\* and \* indicate significance at the 0.01%, 0.05% and 0.1% level respectively. All models use the within transformation (fixed effects) to handle the firm specific constants. The estimation method is two-step GMM with standard errors robust to arbitrary heteroskedasticity and arbitrary correlation within countries using the xtvreg2 package

<sup>24</sup> Results not shown here.

for Stata. In the estimation of (1) and (2) the time dummies are “partialled out”, to obtain the covariance matrix of orthogonality conditions of full rank.

2) The excluded instruments are the first lag of  $a$  and  $\bar{a}$

3) The excluded instruments are the first lag of  $a$ ,  $\bar{a}$ ,  $s$  and  $ebitda/customer$

4) All diagnostics report robust p-values. Hansen J is the Sargan-Hansen test of over-identifying restrictions. Endogeneity is a test of the null hypothesis that  $a$  and  $\bar{a}$  are exogenous.

The coefficients are fairly stable across specifications. Except for the exactly identified models (1) and (1a), the coefficients are significant at the 5% level for the models with time dummies, and at the 1% level for the models without time dummies. In all models the coefficients have the expected sign - an increase in the own MTR increases  $y_{it}$ , and an increase in competitors’ average MTR decreases  $y_{it}$ . Moreover, the coefficients are close to 1 and -1 as predicted by the theoretical model.

The preferred model is regression (2) since this is both overidentified and robust to unobservable time shocks. The last row in Table 3 reports the test statistics for the null hypothesis that  $a_{it}$  and  $\bar{a}_{-it}$  are in fact exogenous variables. Exogeneity is rejected at the 10% level for model (2), but not for the other models. All in all the results are inconclusive as to whether the MTRs are in fact endogenous. Given our reliance on model (2) and the possibility that some MTRs are set endogenously, we do not impose exogeneity.

Consider the profit neutrality hypothesis. Let  $a(h) = \{a_{1t} + h, a_{2t} + h, \dots + a_{Nt} + h\}$ .

Using (6) and (7) we find that profit neutrality requires that

$$\frac{\partial \pi_{it}}{\partial h} = s_{it}^2 X \left( \beta_1 + \beta_2 + 2 \frac{\partial s_{it}}{\partial h} \frac{\pi_{it}}{s_{it}} \right) = 0, \quad \forall i. \quad (8)$$

A key property of the theoretical model is that market shares are unaffected by an identical change in all MTRs in the market i.e.,  $\partial s_{it} / \partial h = 0$ . We leave this as an untested assumption in this paper.<sup>25</sup> Conditioned on this, we see from (8) that profit

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<sup>25</sup> We have not attempted to estimate market shares as a function of termination rates in this paper. The reason is lack of instruments: Market shares are subject to a high degree of inertia. Hence, contrary to when estimating profit functions, we cannot use lagged values of termination rates as instruments.

neutrality requires that  $\beta_1 + \beta_2 = 0$ . Table 4 below shows the results of testing profit neutrality based on the previous empirical results.

**Table 4. Tests of profit neutrality**

|                          | 1    | 2    | 1a   | 2a   |
|--------------------------|------|------|------|------|
| H0: $\beta_1 = -\beta_2$ | 0.09 | 0.13 | 0.07 | 0.09 |

Note: P-values reported. Test statistics are obtained from the corresponding models in Table 3.

As seen from Table 4, neither model rejects the null at the 5% level. The preferred model, 2), does not reject the null at the 10% level (prob value=0.13). We conclude that we cannot reject that the operator's profits are unaffected by an identical change in all MTRs<sup>26</sup>.

## 5. Concluding remarks

The wide-ranging theoretical literature on mobile termination rates (MTRs) is inconclusive on how the level of MTRs affects overall consumer charges and firms' profit. It depends on retail price structures, relative size of fixed-mobile traffic and degree of market saturation. The empirical literature on the topic is sparse. The present paper contributes to this literature in that we estimate mobile networks' profit as a function of all MTRs in the market. Our model fits to key market features by allowing for competition between n-firms, asymmetric MTRs, differences in marginal costs and vertical differentiation.

We show that an identical increase in all MTRs has a positive, but insignificant, impact on firms' profit. Hence, the results suggest that the level of the MTRs cannot be used by operators as a collusive device, and provide support for policy makers' tendency not to worry about the fact that low MTRs may facilitate collusion. On the other side, while we do not have data on retail prices, the results indicate that a reduction in MTRs levels

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<sup>26</sup> It should be mentioned that this does not mean that we can accept the null hypothesis. Indeed, neither can we reject that there is a small but positive effect on operators' profit.

will not necessarily be an effective instrument to ensure benefit to the consumers as conjectured by the policy makers.

What begs a question is if the level of MTRs does not have a significant impact on profit, why do firms care so much about policy makers' attempt to lower MTRs? One explanation is that firms do not perceive MTRs as reciprocal, and the battle for maintaining the level may be blurred by the battle for maintaining own MTR relatively high. In line with theoretical predictions, our econometric results show that an increase in a firm's own MTR will increase profit and an increase in the average MTR of the other mobile firms will decrease profit. Another explanation might be that a MTR level approaching zero may alter the industry structure by facilitating entry from internet based firms with an ad-financed retail business model. Today an internet telephony provider (like Skype) needs to employ a user-financed business model to support interconnection with traditional telecommunication operators. A topic for further research may thus be the interplay between MTRs and ad-financed retail players.

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## Appendix A

We now introduce a fixed network into the model in Section 2. We show that, under circumstances described below, it will not have qualitative implications for the model predictions or the empirical results.

Traffic to and from a fixed network can be included in profit expression (1.) in the following way:

$$\pi_i = s_i X \left( p_i - 2c_i + \sum_{j \neq i} s_j (a_i - a_j) + x_{fm} a_i - x_{mf} a_f \right). \quad 1b)$$

Where  $a_f$  is the cost per minute for terminating calls on the fixed network. The volume of calls per customer on the mobile network going to and from the fixed network is  $x_{mf}$  and  $x_{fm}$ , respectively. We make the following assumptions with respect to cross price effects:

$$\frac{\partial x_{mf}}{\partial p_i} = 0 \quad A.3)$$

$$\frac{\partial x_{fm}}{\partial p_i} = 0 \quad A.4)$$

The two additional assumptions above are sufficient conditions for concluding that adding a fixed network does not change the profit function derived in proposition 1. This can be verified by differentiating (1b) with respect to  $p_i$  inserting it back into the profit expression and deploying assumptions A.1) to A.4). Notice, however, that the rule for optimal pricing (equation 3.) changes. Costs and revenues related to exchanging calls with the fixed network will be reflected in the end user prices.

It can be argued that both of the additional assumptions are plausible given assumptions already deployed in the present paper. We assume that consumers buy a bundle with included usage. Assumption A.3) is a direct extension of this bundling assumption. Assumption A.4) implies zero cross price effect related to  $p_i$ .

## Appendix B

**Table B1. Termination rates and profit. GMM fixed effects, no clusters**

$$\text{Model: } y_{it} = \gamma_i + \beta_1 a_{it} + \beta_2 \bar{a}_{-it} + v_{it}$$

|                 | (1)             | (2)             | (1a)            | (2a)            |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| $a_{it}$        | 1.17<br>(0.46)  | 1.20<br>(0.45)  | 1.16<br>(0.50)  | 1.26<br>(0.49)  |
| $\bar{a}_{-it}$ | -0.57<br>(0.45) | -0.66<br>(0.44) | -0.62<br>(0.48) | -0.74<br>(0.48) |
| Time dummies    | Yes             | Yes             | No              | No              |
| R2              | 0.17            | 0.16            | 0.05            | 0.05            |
| N               | 236             | 231             | 236             | 231             |
| N_g             | 22              | 21              | 22              | 21              |
| Hansen J        |                 | 0.48            |                 | 0.58            |
| C Statistics    |                 | 0.59            |                 | 0.64            |
| Endogeneity     | 0.08            | 0.06            | 0.15            | 0.10            |

Notes, see Table 3.

## Appendix C

Table C1. First stage regressions\*

|                         | (1)              | (1a)            | (2)              | (2a)             |
|-------------------------|------------------|-----------------|------------------|------------------|
|                         | $a_{it}$         | $\bar{a}_{-it}$ | $a_{it}$         | $\bar{a}_{-it}$  |
| $a_{it-1}$              | 0.78<br>(11.24)  | 0.14<br>(2.70)  | 0.83<br>(18.09)  | 0.15<br>(3.12)   |
| $\bar{a}_{-it}$         | -0.08<br>(-1.28) | 0.55<br>(7.29)  | -0.12<br>(-3.24) | 0.55<br>(7.83)   |
| $s_{it-1}$              |                  |                 | -6.59<br>(-0.43) | 8.65<br>(0.45)   |
| $(ebitda / cust)_{t-1}$ |                  |                 | -0.05<br>(-1.45) | -0.06<br>(-3.39) |
| $y_{it-1}$              |                  |                 |                  |                  |
| Shea R <sup>2</sup>     | 0.45             | 0.44            | 0.47             | 0.45             |
| N                       | 236              | 236             | 231              | 231              |
| N_g                     | 22               | 22              | 21               | 21               |

\* t values in parentheses.

## Appendix D

**Table D1. Termination rates and profits: Arellano-Bond dynamic panel<sup>1</sup>**

$$\text{Model: } y_{it} = \gamma_i + \beta_0 y_{it-1} + \beta_1 a_{it} + \beta_2 \bar{a}_{-it} + v_{it}$$

| Variable                        | (1) <sup>2</sup> | (2) <sup>2</sup> |
|---------------------------------|------------------|------------------|
| $y_{it-1}$                      | 0.02<br>(0.09)   | 0.07<br>(0.10)   |
| $a_{it}$                        | 1.10<br>(0.73)   | 1.45*<br>(0.83)  |
| $\bar{a}_{-it}$                 | -0.61<br>(0.90)  | -1.15<br>(0.89)  |
| Time dummies                    | yes              | no               |
| Obs                             | 228              | 228              |
| Firms                           | 21               | 21               |
| <i>Diagnostics</i> <sup>3</sup> |                  |                  |
| AR(1)                           | -1.78*           | -1.71*           |
| AR(2)                           | -0.04            | -0.27            |
| Sargan                          | 1.94             | 18.29            |

Notes:

1) The variables are defined in Table 1. Robust standard errors in parentheses. \* denote significance at the 10% level. The model uses first differences to handle the firm specific effects. The estimation method is Arellano-Bond dynamic panel data using the xtabond package for Stata, see Arellano and Bond (1991). The reported estimates are first step, except Sargan which is two-step.

2)  $a_{it}$  and  $\bar{a}_{-it}$  are treated as endogeneous with the second lags of  $s$  and  $ebitda/cust$  as additional instruments. All valid orthogonality conditions up to 5 lags are used.

3) AR(1) is the Arellano-Bond test that average autocovariance in residuals of order 1 is 0, AR(2) is the corresponding test of average autocovariance of order 2. Sargan is the Sargan-Hansen test of over-identifying restrictions. The p-values of both Sargan statistics are 1, note however that the Sargan-Hansen statistics in these models are well known to have little power.

