Mobile Number Portability*

Stefan Buehler†

University of Zurich and University of St. Gallen

Justus Haucap‡

Ruhr-University of Bochum

July 2004

Abstract

This paper examines the consequences of introducing mobile number portability (MNP). We show that if the sole effect of introducing MNP is the abolishment of switching costs, MNP benefits mobile customers. However, if MNP also causes consumer ignorance, as telephone numbers no longer identify networks, mobile operators increase termination charges, with ambiguous net effect on the surplus of mobile customers. We examine how extensions such as MNP based on call-forwarding, termination fee regulation, and alternative means of carrier identification affect these findings and discuss policy implications.

Keywords: number portability, switching costs, telecommunications, network competition

JEL Classification: L13, L51, L96.

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1 Introduction

Mobile number portability (MNP) requires that mobile telephone customers can keep their telephone number—including the prefix—when switching from one provider of mobile telecommunications services to another. In the absence of MNP, customers have to give up their number and must adopt a new one when they switch operators. As a result, customers face switching costs associated with informing people about changing their number, printing new business cards, missing valuable calls from people that do not have the new number, etc. Based on these considerations, many regulatory authorities have imposed mandatory MNP—or are about to require its introduction—so as to reduce customers' switching costs, attempting to make mobile telecommunications more competitive (see, e.g., Reinke, 1998).

The world's first country to introduce MNP was Singapore in 1997, followed by the UK, Hong Kong and the Netherlands in 1999. As of 2003, a number of other countries, especially in Europe, require MNP (see Table 1).

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Table 1: Introduction of MNP in Selected Countries

Year	Countries where MNP is available
1997	Singapore
1999	UK, Hong Kong, Netherlands
2000	Spain, Switzerland
2001	Australia, Sweden, Denmark, Norway
2002	Belgium, Italy, Portugal, Germany
2003	USA, Ireland, France, Finland, Luxembourg
2004	Austria, Greece, Hungary
not clear	Canada, New Zealand, Japan, South Korea, Taiwan, Mexico

Sources: European Commission (2002), INTUG (2003); own research

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The rationale of introducing MNP is simple: MNP is expected to bring about considerable benefits to users of mobile telephony services (see, e.g., Oftel, 1997; NERA/Smith, 1998;. Ovum, 2000). Adopting the classification originally proposed by NERA when it considered the case of introducing number portability for fixed line services in the UK in the mid 1990s, Table 2 lists four types of consumer benefits that have been examined as part of the various cost-benefit-analyses conducted for advising regulatory authorities' on MNP.

Much of the analysis has focused on type 1 and type 2 benefits, since type 3 benefits are usually considered to be relatively small (see, e.g., Oftel, 1997; Ovum, 2000; Schwarz-Schilling and Stumpf, 1999). In the academic literature, type 2 benefits have received

Table 2: Benefits of MNP		
Type of Benefit	Applies to	Benefit
1A	Users who switch even without MNP	Avoided costs of number change (e.g. informing users, lost calls)
1B	Users who only switch with MNP	Benefits of moving to a new operator
2	All users	Benefits of stimulating competition
3	Callers	Avoided costs of finding changed numbers

<div align="center">Source: Oftel (1997, p.4), Ovum (2000, p.7)</div>

special attention. The intuitive notion that number portability enhances competition due to reduced switching costs has formally been analyzed by Aoki and Small (1999), who examine the welfare effects of MNP for different levels of mobile penetration (or market saturation). They find that the overall welfare effect of MNP is ambiguous if the investment or set-up costs of implementing MNP are weighed against the benefits of more intense competition between mobile operators. In related papers, Gans, King and Woodbridge (2001) and Haucap (2003) have focused on the question of how to allocate the property rights in telephone numbers and the costs of implementing number portability.

An important aspect that has largely been ignored in this debate is the fact that MNP can make it more difficult for consumers to distinguish between different networks when placing a call. In the absence of MNP, consumers can usually distinguish between different mobile networks through the number prefix.[1] When MNP is introduced, however, the number prefix does not automatically indicate the network assignment of a given number. As a result, if calling prices differ between different networks (as they usually do), consumers may be unaware of the exact charges for placing calls to mobile networks. As Ovum (2000, p.14/15) acknowledges in its cost-benefit-analysis of MNP in Ireland,

> "the first three digits of the called number no longer indicate the network
> operator of the called subscriber reliably. Full tariff transparency is therefore

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[1]For example, in New Zealand all *Vodafone* numbers start with the prefix 021 while *Telecom New Zealand* uses the 025 numbering range. Similarly, in Ireland *Meteor* allocates seven digit subscriber numbers from behind the code 085, *Digifone* allocates subscriber numbers from behind the code 086 and *Eircell* allocates subscriber numbers from behind the code 087. In Austria, *tele.ring*'s numbering range starts with 0650, while *H3G* uses 0660, *mobilkom* uses 0664, *T-Mobile* 0676 and *One* 0699. In Switzerland, *Swisscom* uses the prefix 079, whereas *Orange* and *Sunrise* use the 078 and 076 numbering ranges, respectively.

lost and, unless prices change, callers end up paying a lot more than expected for certain calls. [...But] it is difficult to quantify these effects and we have excluded them from our cost benefit analysis."

The effects of consumer ignorance with respect to relevant prices have recently been explored by Gans and King (2000) and Wright (2002). They show that mobile operators may have incentives to increase their termination charges if consumers only take notice of average prices. Furthermore, they suggest that MNP may deteriorate the customers' price information. However, they do not formally work out the argument or analyze the trade offs associated with the introduction of MNP.

The present paper aims to fill this gap by analyzing the potential trade off between more intense competition and (increased) consumer ignorance associated with MNP. We start with the simple case where the only effect of introducing MNP is the abolishment of switching costs. For this case, we find that the conventional wisdom holds that introducing MNP unambiguously benefits mobile customers.

Next, we examine the case where introducing MNP not only abolishes switching costs, but also gives rise to a consumer ignorance problem. Allowing for more subtle price effects of MNP than previous studies,[2] we find that the effect of introducing mandatory MNP on the surplus of mobile customers and overall welfare is ambiguous.[3] More specifically, we show that, in this case, the introduction of mandatory MNP is less likely to generate welfare gains (i) the closer substitutes mobile networks are, and (ii) the larger the market for fixed line telephony.

The intuition of these results is straightforward: If mobile networks are close substitutes and competition is thus intense, introducing MNP does not strongly affect the consumers' subscription decisions. That is, the benefits of introducing MNP are small. However, the costs of introducing MNP persist if consumers are unaware of specific termination charges and thus base their calling decisions on average prices. This induces mobile operators to increase their termination charges, thereby adversely affecting the fixed line telephone customers. The latter effect is more pronounced if the market for fixed line telephony is large.

Having identified why the introduction of MNP may generate adverse welfare effects, we examine a number of extensions to our analysis. First, we analyze how our results

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[2]Some of these studies simply assumed that MNP will generate a drop in mobile prices across the board (see, e.g., Ovum, 2000, p.13, or Schwarz-Schilling and Stumpf, 1999).

[3]In contrast, if customers are ignorant irrespective of MNP or if a jurisdiction does not have mobile network specific prefixes (as, e.g., in the US), introducing MNP has no effect on the transparency of mobile tariffs. We are then back to the first case, where introducing mandatory MNP unambiguously benefits mobile customers.

are affected if MNP is implemented using "call-forwarding" rather than an "Intelligent Network" (IN) solution, where call-forwarding typically features higher marginal costs (due to inefficient rerouting) but lower fixed costs than the IN technology. We find that due to higher termination charges, both fixed line and mobile customers are worse off with call-forwarding. However, since investment costs are typically lower with call-forwarding, the welfare comparison with the IN solution is ambiguous.

Second, we show that with regulated termination charges, the case for introducing MNP becomes much stronger. This follows from the fact that under this type of regulation, introducing MNP is unlikely to affect termination charges. Therefore, both fixed line and mobile customers are (weakly) better off, and introducing MNP is thus welfare improving if investment costs are not prohibitive.

Finally, we consider the case where MNP is supplemented by alternative means to identify networks (such as an acoustic signal or toll-free enquiry numbers). We find that such alternative means help generating positive welfare effects if the costs of implementing them are not too high (and the nuisance to customers is small).

The remainder of the paper is organized as follows. In Section 2 we introduce the analytical framework and present the key results of our analysis. In Section 3, we examine a number of extensions outlined above. Finally, section 4 discusses policy implications and concludes.

2   The Model

There are two mobile networks $i = A, B$ and a fixed line telephony market of size $k > 0$. We assume that fixed and mobile telephony constitute two different markets, so that there is no intermodal competition between fixed and mobile operators. The mobile networks are assumed to be differentiated along a Hotelling line of length 1 with network A being located at 0 and network B at 1. Suppose that A is the incumbent mobile operator while firm B is a new entrant. Without MNP, consumers face a switching cost $S \geq 0$ when changing from A to B. Hence, S reflects the consumers' valuation of keeping their telephone number. In addition, suppose that consumers are uniformly distributed between 0 and 1. Finally, assume that for given income y, a consumer located at x receives utility U_A and U_B when joining network A or B, respectively, with

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\begin{aligned}
U_A &= y + v_0 - \tau x + u(q), \\
U_B &= y + v_0 - S - \tau(1-x) + u(q).
\end{aligned}
$$

Here, v_0 denotes a consumer's intrinsic value of being connected to a mobile telephone network, and τ reflects the degree of network differentiation. The term $u(q)$ measures

consumers' utility from making calls so that for a given call price p consumers' indirect utility is given by $v(p) \equiv \max_q(u(q) - pq)$, i.e. we assume that consumers are indifferent to incoming calls.[4]

We consider the case where mobile operators $i = A, B$ compete in non-linear prices, i.e. they choose two-part tariffs consisting of a fixed subscription fee F_i and variable service charges p_{ij} for mobile services (such as calls, SMS, etc.) indexed by $j = 1, ..., n$. Hence, mobile operator i offers a tariff function

$$W_i(q_{i1}, ..., q_{in}) = F_i + \sum_{j=1}^{n} p_{ij} q_{ij}, \quad i = A, B.$$

It is well known that firms set service charges at marginal cost when they can set multi-part tariffs, i.e. $p_{ij} = c_{ij}$.[5] For simplicity, we follow Wright (2002) and Gans and King (2000) in focusing our analysis on fixed-to-mobile calls, ignoring the more complex issue of mobile-to-mobile interconnection.[6] We also assume that firms' marginal costs are constant and symmetric. Given these assumptions, the market share of mobile operator A is given by

$$s_A = \frac{1}{2} + \sigma S + \sigma(F_B - F_A),$$

where $\sigma \equiv 1/(2\tau)$ is a measure of the substitutability of mobile networks, and $s_B = 1 - s_A$. As is well known from the literature, an interior equilibrium exists only if σ and S are not too high.[7]

Regarding the fixed network, let us assume that consumers' indirect utility from calling people on their mobile network is given by the quadratic function $\varphi(p) = (a - bp_F)^2/2$ where p_F is the price for a fixed-to-mobile call. Hence, we obtain a linear demand function $q(p_F) = a - bp_F$ for fixed-to-mobile calls.

Finally, we assume that mobile networks set their termination charges t_i for fixed-to-mobile calls simultaneously. If the fixed network is able to set multi-part tariffs, the prices for fixed-to-mobile calls will be given by $p_{Fi} = t_i$ for $i = A, B$. The marginal cost for terminating fixed-to-mobile calls is denoted by c_T and assumed to be symmetric for the two mobile networks.

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[4]Apart from the incorporation of switching costs, this is the basic set-up of virtually all network competition models as introduced by Laffont, Rey and Tirole (1998) and Armstrong (1998). It is also used in the literature referenced above, i.e. Aoki and Small (1999), Gans and King (2000) and Wright (2002).

[5]Intuitively, by setting service charges equal to marginal cost firms maximize the consumers' surplus that they can extract using the fixed fee (see, e.g., Laffont, Rey and Tirole, 1998).

[6]The analysis of mobile-to-mobile calls is more complex since changes in the relevant termination charges also affect the market shares of mobile networks.

[7]More specifically, we constrain our analysis to cases where $2\sigma S \leq 3$. Otherwise A would capture the entire market so that B would not have entered the mobile market in the first place.

2.1 Competition without MNP

In the absence of MNP, the incumbent mobile network A typically has a competitive advantage, as consumers face switching costs $S \geq 0$ when switching to operator B. Furthermore, the customers of the fixed network can perfectly distinguish the mobile networks $i = A, B$ through their numbering prefixes. Hence, assuming a balanced calling pattern, network i's profit is given by

$$\pi_i = s_i F_i + k s_i (t_i - c_T)(a - b t_i), \quad i = A, B. \tag{1}$$

The first term reflects the profit generated by the subscription fee charged to i's customer base. The second term represents the profit from fixed-to-mobile calls terminated on network i.[8] Maximizing over F_i and t_i yields

$$t_A^m \quad = \quad t_B^m = \frac{1}{2b}(a + b c_T), \tag{2}$$

$$F_A \quad = \quad \frac{1}{2\sigma} - \frac{1}{4}\frac{k}{b}(a - b c_T)^2 + \frac{1}{3}S, \tag{3}$$

$$F_B \quad = \quad F_A - \frac{2}{3}S. \tag{4}$$

Since both mobile operators have monopoly power over the calls that are being made to their customers, it is not surprising that both termination charges are set at the monopoly level $t_A^m = t_B^m$ (see (2)).[9] However, as (3) and (4) indicate, the associated monopoly profits of $(k/4b)(a - b c_T)^2$ are entirely used to "subsidize" the mobile customers' subscription fees F_A and F_B. Nevertheless, the incumbent operator A is able to charge a higher fixed fee than operator B, since A can exploit its customer base facing switching costs $(F_A > F_B)$. Put differently, operator B has to offer a lower fixed fee to attract consumers. For later reference, note that equilibrium market shares are given by $s_A = (1/2) + (1/3)\sigma S$ and $s_B = (1/2) - (1/3)\sigma S$, and firms' profits are $\pi_i = s_i^2/\sigma$ for $i = A, B$.

2.2 The Case for MNP

It is conventional wisdom that introducing MNP benefits consumers, as it makes the market for mobile telecommunications services more competitive. In this section, we

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[8] Recall that all other service charges are set so as to equal marginal cost, i.e. the corresponding terms are equal to zero.

[9] Note that our analysis differs here from Gans and King (2000) and Wright (2002) as we assume that termination charges and subscription fees are set simultaneously, while Gans and King (2000) and Wright (2002) assume that subscription fees are chosen once the termination rates have been set.

briefly show that this rationale is correct if the sole effect of introducing MNP is the abolishment of switching costs.[10] To do so, we make the following assumption:

Assumption 1 *With MNP, consumers face no switching costs $(S = 0)$.*

As in the absence of MNP, (1) is network i's profit function. The profit maximizing termination charges and fixed fees are thus given by (2),(3), and (4), with switching costs set to zero $(S = 0)$ by Assumption 1. It follows immediately that introducing MNP leaves termination charges unaffected, whereas it decreases F_A and increases F_B. That is, the customers of the larger network A benefit from a reduction of fixed fees, whereas the customers of the smaller network B suffer from an increase in fixed fees. It is straightforward to show that the beneficial effect on the customers of the larger network A dominates the adverse effect on the customers of the smaller network B, giving rise to a positive overall price effect on mobile customers.[11]

All other effects on mobile customers are positive as well. After all, customers of network B directly gain from the removal of switching costs, as their utility is no longer reduced by S. In addition, MNP implies that the customers' subscription decisions are not distorted by switching costs, and the customers' average "transport" costs are thus lower than without MNP. Together, all these effects assure that introducing MNP benefits mobile customers if its only implication is the abolishment of switching costs.

We shall argue below that the picture is less clear once one accounts for the fact that MNP makes it difficult for fixed telephony costumers to distinguish between different networks when placing a call.

2.3   The Consumer Ignorance Problem

Let us now assume that in addition to abolishing switching costs, MNP implies that fixed telephony customers cannot determine ex ante which mobile network they are calling when placing a call to a particular number.[12] More specifically, we make the following additional assumption:

Assumption 2 *With MNP, consumers base their calling decision on the average price for fixed-to-mobile calls, i.e. $\overline{p}_F = s_A t_A + s_B t_B$.*

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[10]In the next section, we will argue that introducing MNP may also bring about a consumer ignorance problem.

[11]Using (3) and (4), the overall price effect on mobile customers is $s_A F_A + (1 - s_A)F_B - F_A|_{S=0} = \frac{2}{9}\sigma S^2 > 0$.

[12]Equivalently, customers do not know ex ante the price of the service they wish to purchase.

This assumption reflects the notion of consumer ignorance proposed by Gans and King (2000), which assumes that consumers base their calling decisions on the average price for fixed-to-mobile calls.[13]

Using Assumptions 1 and 2, mobile operator i maximizes

$$\pi_i = s_i F_i + k s_i (t_i - c_T)(a - b(s_i t_i + (1 - s_i) t_j)), \quad \text{for } i, j = A, B \text{ and } j \neq i.$$

Maximizing over F_i and t_i now yields

$$t_A^{MNP} = t_B^{MNP} = \frac{1}{3b}(2a + bc_T), \tag{5}$$

$$F_A^{MNP} = F_B^{MNP} = \frac{1}{2\sigma} - \frac{2}{9}\frac{k}{b}(a - bc_T)^2. \tag{6}$$

Thus, the introduction of MNP removes the networks' asymmetry, so that mobile operators charge both the same termination and subscription fees and, accordingly, have the same market shares $s_A^{MNP} = s_B^{MNP} = 1/2$.

It is important to note that both network operators increase their termination charges for fixed-to-mobile calls ($t_i^{MNP} > t_i, i = A, B$). This follows from the fact that operator i does not bear the full consequences of increasing its termination charge t_i, since consumers base their calling decisions on the average price $\overline{p}_F$ rather than individual prices t_i. That is, operators exert a *negative externality* on each other when increasing their termination charges. Since this externality leads to termination charges above the monopoly level, the operators' profits from fixed-to-mobile calls decrease, and hence the "cross-subsidies" towards the fixed fee must also decrease.

Condition (6) further indicates that F_B unambiguously increases with the introduction of MNP. With the asymmetry between networks removed, B no longer has an incentive to offer a discount (relative to A) so as to induce mobile customers to switch. In addition, the funds available for "cross-subsidization" are reduced, which reinforces the increase of F_B. The effect on the incumbent's subscription fee F_A is less clear-cut. Both the "cross-subsidization" and the incumbency advantage are reduced, with ambiguous net effect on F_A.[14] Finally, note that firms' profits are still given by $\pi_i = s_i^2/\sigma$.

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[13]Assumptions 1 and 2 may be considered extreme, as in practice MNP will neither completely eliminate consumer switching costs, nor lead to complete consumer ignorance. Nevertheless, we think that they are useful in the present context, since they simplify the analysis, without undermining the basic trade off under study (reduced switching costs v. reduced tariff transparency). In fact, while we overstate the potential cost of MNP that results from reduced tariff transparency, we also overplay its benefits as the switching cost may still be larger than zero in reality even with MNP.

[14]More specifically, the introduction of MNP will strictly reduce A's fixed fee ($F_A^{MNP} < F_A$) if the switching cost without MNP is sufficiently high, i.e. $S > \frac{1}{12}\frac{k}{b}(a - bc_T)^2$.

2.4 Distributional and Welfare Effects of MNP with Consumer Ignorance

Our above analysis indicates that introducing MNP is likely to bring about considerable changes in the market for mobile services. To identify the winners and losers of introducing MNP, we now consider each of the groups affected: The mobile operators A and B, the customers of the fixed network placing fixed-to-mobile calls, and the customers of mobile operators. Finally, we discuss the overall effect of introducing MNP on social welfare.

(a) Mobile Operators

As indicated above, the profits of mobile operators are given by $\pi_i = s_i^2/\sigma, i = A, B$, both with and without MNP. This implies that the mobile operators' profits are convex in own market shares. Since MNP aligns the mobile operators' market shares, introducing MNP will decrease aggregate profits of mobile operators. More specifically, the extra profits awarded to B are smaller than the profit reduction of the incumbent A. An obvious loser is thus the incumbent mobile operator A. The competitor B, in contrast, benefits from introducing MNP. In general, we should expect the incumbent A to oppose the introduction of MNP, whereas the competitor B will typically support it.

(b) Fixed Network Customers

It is probably less obvious that the customers of the fixed network are adversely affected by the introduction of MNP. To see this, recall that—due to the consumer ignorance problem—mobile operators raise their fixed-to-mobile termination charges above the monopoly level ($t_i^{MNP} > t_i$ for $i = A, B$) when MNP is introduced. Since the fixed network sets non-linear prices, the variable prices for fixed-to-mobile calls equal their marginal costs, which are equivalent to the termination charges. Introducing MNP thus raises the variable prices paid by fixed network customers, decreasing their indirect utility.[15]

(c) Mobile Customers

One might expect that mobile customers always benefit from MNP. As noted above, customers of network B directly gain from the removal of switching costs, as their utility is no longer reduced by S. In addition, consumers' average "transport" costs decrease.[16] However, the fixed fee for customers of network B will generally increase, while F_A may

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[15]More precisely, the fixed network customers' indirect utility decreases by $k(a - bc_T)^2/8 - k(a - bc_T)^2/18 > 0$.

[16]Customers with a preference for network B will no longer choose A simply because of the existence of switching costs.

fall or raise, depending on parameter values.[17] Hence, the overall effect of MNP on the consumers' surplus, denoted by $\Delta CSM \equiv CSM^{MNP} - CSM$, is ambiguous once one accounts for the consumer ignorance problem.

However, it is not difficult to see that mobile customers are unlikely to benefit from the introduction of MNP when mobile networks are close substitutes (σ is high) and the market for fixed line telephony is large (k is high). Intuitively, if mobile networks are close substitutes, competition is intense even in the absence of MNP, and thus the benefits of introducing MNP are necessarily relatively small. The costs of introducing MNP to mobile customers, in turn, are particularly large if the market for fixed line telephony is large: Mobile operators are then able to generate sizeable funds from the fixed-to-mobile monopolies to "cross-subsidize" subscription fees. Introducing MNP reduces these cross-subsidies—as mobile operators no longer charge monopoly termination charges—, raising the subscription fees for mobile customers.[18]

Alternatively, we may characterize ΔCSM by referring to the various types of consumer benefits listed in Table 2. First, recall that benefits of type 1A result from the avoided costs of number changes, i.e. they accrue to consumers who switch even in the absence of MNP. In our model, there are $(\frac{1}{2} - \frac{1}{3}\sigma S)$ consumers who switch to network B even in the absence of MNP, so that the total switching costs saved with MNP amount to $(\frac{1}{2} - \frac{1}{3}\sigma S)S$. Second, benefits of type 1B—those associated with moving to a new operator—accrue to consumers who only switch with MNP (but not without MNP). In our model, once MNP is implemented, these customers save the "transport" costs $\frac{1}{18}\sigma S^2$ of subscribing to their less preferred network. Since more consumers subscribe to the network of their choice with MNP, these customers save the "transport" costs of being, without MNP, connected to the less liked network. Third, benefits of type 2 associated with more intense competition result from changes in the fixed fees that mobile consumers have to pay.[19] As is easily verified, the sum of the benefits of type 1A, 1B and 2 is equivalent to ΔCSM.

(d) The Effect on Social Welfare

Let us finally consider the effect of introducing MNP on social welfare, denoted by $\Delta W \equiv W^{MNP} - W$. Suppose that there is an exogenous investment cost, say I, associated with the implementation of MNP. Now, let I^* denote the critical level of investment costs below which the introduction of MNP is desirable from a welfare point

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[17]The average subscription fee will fall with the introduction of MNP iff $k < 8b\sigma S^2/(a - bc_T)^2$.

[18]See Appendix 5.1 for a more formal analysis.

[19]More formally, type 2 benefits total $s_A F_A + (1 - s_A)F_B - F_A^{MNP} = \frac{2}{9}\sigma S^2 - \frac{1}{36}\frac{k}{b}(a - bc_T)^2$.

of view.[20] Straightforward calculations show that $\partial I^*/\partial\sigma < 0$ and $\partial I^*/\partial k < 0$. That is, the maximum level of investment costs that still ensures a welfare improvement from MNP is small when mobile networks are close substitutes (σ is high) and the market for fixed line telephony is large (k is high). The intuition is simple: If mobile networks are close substitutes, the benefits of MNP to mobile customers are relatively small. Furthermore, if the market for fixed telephony is large, the adverse effect on fixed-line telephony customers is more pronounced. Thus, when σ and k are large, there is little room for MNP to increase overall consumer surplus. As a result, the investment cost for MNP must be small to make the introduction of MNP socially desirable.

3   Extensions

We now consider three natural extensions of our model. First, we study the introduction of MNP using a "call-forwarding" solution, which typically involves lower investment costs but also leads to higher conveyance costs than those considered above (see, e.g., Oftel, 1997). Second, we examine how the results of our analysis change if mobile termination charges are regulated, so that mobile operators cannot exploit consumer ignorance by increasing termination charges. Finally, we examine to what extent alternative carrier identification mechanisms may solve the consumer ignorance problem.

3.1   Call-forwarding Solutions

So far, we have implicitly assumed that MNP is introduced using an Intelligent Network (IN) solution that involves some investments costs I, while keeping the call carriage costs constant. If, however, MNP is implemented by "call-forwarding" rather than an IN solution, the assumption of constant conveyance costs is no longer realistic: Solutions based on call-forwarding typically lead to an increase in conveyance costs, as calls are routed relatively inefficient over the network (see, e.g., Oftel, 1997, Ovum, 2000). At the same time, the fixed costs associated with call-forwarding are typically smaller than those of an IN solution.

To account for the possibility of implementing MNP by call-forwarding, let us assume that, under call-forwarding, the marginal call termination cost is given by $c_T^{CF} > c_T$, whereas the the fixed investment cost is $I^{CF} < I$, with the superscript CF denoting

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[20]In equilibrium, this critical level of investment costs is given by

$$I^* = \frac{1}{2}S - \frac{2}{9}\sigma^2 S^2 - \frac{1}{18}\sigma S^2 - \frac{k}{72}(5 + \frac{2}{b})\left(a - bc_T\right)^2 .$$

call-forwarding. The mobile networks' tariff structure then changes to

$$t_A^{CF} \quad = \quad t_B^{CF} = \frac{1}{3b}(2a + bc_T^{CF}), \tag{7}$$

$$F_A^{CF} \quad = \quad F_B^{CF} = \frac{1}{2\sigma} - \frac{2}{9}\frac{k}{b}(a - bc_T^{CF})^2. \tag{8}$$

Comparison of (5) and (7) indicates that fixed-to-mobile termination charges are higher under call-forwarding than under an IN solution, leading to a lower volume of fixed-to-mobile calls and, accordingly, to lower total profits generated from these calls. This, in turn, implies that there is less money available to subsidize mobile customers' subscription fees, so that $F_i, i = A, B$, increases. As a result, mobile customers' surplus is clearly higher under an IN solution than under call-forwarding. That is, from the mobile customers' point of view, it is always preferable to implement mobile number portability by an IN rather than a call-forwarding solution.

In terms of overall welfare, the comparison between the IN and a call-forwarding solution is ambiguous, since the investment costs of a call-forwarding solution are lower. Intuitively, the additional investment costs associated with an IN solution may be the larger, the larger the increase in conveyance costs associated with call-forwarding, and the larger the fixed-to-mobile market (k) who suffers from this cost increase. That is, the IN solution is more attractive, the less efficient the routing of calls with call-forwarding, and the larger the market that is adversely affected by the price increases generated by inefficient call routing.[21]

3.2 Regulated Termination Charges

We have pointed out above that introducing MNP is likely to induce mobile network operators to increase their termination charges. It it is therefore interesting to study how regulations of termination charges—which are already in place in a number of countries, at least for some of the firms—relate to the effects of introducing MNP. Let us therefore consider a very simple regulatory framework where the firms' termination charges must satisfy the condition $t_i^m = t_i^{MNP} \equiv t^R, i = A, B$, where the superscript R indicates regulated termination charges.

Under this regulatory framework, introducing MNP cannot not affect fixed-to-mobile termination charges. This implies that the prices for fixed-to-mobile calls remain constant, so that mobile operators continue to "cross-subsidize" mobile subscription fees with the same amount of profits. Note that even though the consumer ignorance problem is not solved, we are back to the case where the sole of effect of introducing MNP

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[21]See Appendix 5.2 for a more formal analysis.

is the abolishment of switching costs. It is thus unsurprising that the effect of introducing MNP on the surplus of mobile customers, ΔCSM, is unambiguously positive if termination charges are regulated. In fact, it is straightforward to show that under these circumstances, introducing MNP improves overall welfare provided that investment costs I associated with MNP are not prohibitive.[22]

Summing up, our analysis suggests that introducing MNP is more likely to increase overall welfare if accompanied with adequate regulation of fixed-to-mobile termination charges, so as to avoid increases in termination charges due to reduced tariff transparency.

3.3   Alternative Means of Carrier Identification

Finally, let us reconsider Assumption 2, which holds that introducing MNP will inevitably increase consumer ignorance. While we have already pointed out that this may not necessarily be the case for countries where carriers cannot be identified via numbering prefixes even before introducing MNP, there may also be alternative means to inform consumers about the network to be called. In Finland and Germany, for example, consumers can call a toll-free enquiry number to learn about users' network association. In Portugal consumers are alerted by an acoustic signal when they place an off-net call. However, such mechanisms usually generate costs on their own, and they are often considered a nuisance by at least a subset of consumers.[23]

The nuisance from alternative means of carrier identification is easily incorporated into our analysis by subtracting an additively separable disutility term d from the demand function. If carrier identification successfully resolves the problem of consumer ignorance, the mobile networks' optimal termination rates are given by

$$t_A^{CI} = t_B^{CI} = (a - d + bc_T)/(2b) \tag{9}$$

Comparing (9) and (5), it follows immediately that to increase the surplus of fixed telephony customers, the nuisance associated with an alternative carrier identification mechanism must be small so as not to outweigh the benefits of overcoming the problem of consumer ignorance.

An equally intuitive result holds for the effect on mobile customers' surplus. They prefer to supplement the introduction of MNP with a carrier identification mechanism if the nuisance of that mechanism is not too large.

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[22]More specifically, given that the industry's profits are reduced by $\frac{2}{9}\sigma^2 S^2$, MNP is welfare enhancing if $I < \frac{1}{2}S - \frac{1}{18}\sigma S^2 - \frac{2}{9}\sigma^2 S^2$.

[23]In fact, Finland introduced an acoustic signal to identify networks when MNP was implemented in 2003. However, since many consumers complained as they found the mechanism annoying, the tone signal was later removed.

Finally, note that in order to generate positive overall welfare effects, the additional investment costs for installing an alternative carrier identification mechanism must be smaller than the benefits of avoiding the consumer ignorance problem

4   Conclusion and Policy Implications

In this paper, we have argued that the introduction of MNP generates various competitive effects that are of potential interest to regulatory authorities. In particular, we have provided an analytical framework for studying the economic costs associated with a reduction in tariff transparency that may result if the prefix of a mobile telephone number no longer indicates its network assignment—an aspect that was largely ignored in previous studies on MNP. Furthermore, we have shown that introducing MNP may have subtle price effects: While the incumbent may lower its fixed subscription fee, the entrant may actually increase it, as it does not have to compete as fiercely for customers as without MNP. Finally, we have shown that depending on the set-up costs, the overall welfare effect of introducing MNP is generally ambiguous.

The introduction of mandatory MNP should be expected to divide providers of mobile services into supporters and opponents: While the new mobile operator benefits, the incumbent will typically lose. Therefore, effects on mobile customers will also be ambiguous. In addition, customers of the fixed network are likely to be adversely affected due to higher termination charges for fixed-to-mobile calls.

Empirically, it is rather difficult to estimate the potential magnitude of the effects described above. This is for three reasons: Firstly, MNP has only recently been introduced in most countries so that the time span is rather short for an empirical analysis. Secondly, very little data is publicly available on consumers' actual switching behaviour. And thirdly, the mobile telecommunications sector is so dynamic with growing demand, changing technologies and changing market structures that it is difficult to empirically isolate the effects of MNP.

Nevertheless, there have been a few cost-benefit analyses of MNP to advice policy makers when mandating MNP. Probably the best known study is the analysis NERA/Smith (1998) conducted for Hong Kong. They estimated, for a 10 year period, a type 1 benefit of 47 to 84 Euros per customer, a type 2 benefit (from increased competition) of 1 Euro per customer and a type 3 benefit of 3 Euros per customer, while the set-up costs for MNP were estimated to range from 23.5 to 36.9 Euros (see NERA/Smith, 1998). In contrast, Oftel (1997) estimated a type 1 benefit of around 52 Euros per customer and a maximum type 2 benefit of 69 Euros. Again, these benefit estimates exceed the estimated set-up costs of 36.4 Euros per customer. Similar esti-

mates have also been reached for Ireland (see Ovum, 2000). Hence, in summary all these studies estimate the benefits to exceed the costs. However, as is explicitly acknowledged in the Ovum (2000, p. 14) study, none of these studies has addressed the potential costs of consumer ignorance.

However, the adverse effects of reduced tariff transparency that we have analysed may be alleviated if either termination charges are regulated or if there are relatively inexpensive alternative means of carrier identification. In fact, MNP and the regulation of mobile termination charges may be complementary from a regulatory perspective: With regulated termination charges, MNP is more likely to be welfare enhancing than without; MNP is clearly welfare enhancing if mobile termination rates are regulated and the set up costs for MNP are not prohibitive. Put differently, the case for regulating mobile termination charges is even stronger with MNP than it may have been without MNP.

Similarly, if comparatively inexpensive alternative means of carrier identification are available, our paper has shown that implementing such means is of great benefit for fixed-line and mobile consumers alike as it resolves the problem of tariff intransparency and the corresponding adverse effects on mobile termination rates.

Hence, taken together we can conclude that MNP will definitely be welfare enhancing if either termination charges are regulated (so that fixed network customers calling mobile phone users are not adversely affected) or if price transparency can be restored by relatively inexpensive means. And obviously, the set-up costs for MNP must not be so high that they exceed the various consumer benefits.

We believe that these findings can be helpful for regulatory authorities debating the introduction of mandatory MNP. One should keep in mind, however, that we have adopted the simplest version of the standard network competition model to explore the competitive effects of introducing MNP. In particular, we have abstracted from the challenging issue of mobile-to-mobile calls and ignored the possibility of further entry into mobile telecommunications markets. Future research into these directions might prove to be instructive for theorists and practitioners alike.

5 Appendix

5.1 The Effect of MNP on Mobile Customers with Consumer Ignorance

Suppose Assumptions 1 and 2 are satisfied. In the absence of MNP, the surplus of mobile customers' is given by

$$
\begin{aligned}
CSM &= y + v_0 + u(q) - s_A F_A - (1 - s_A)(F_B + S) - \tau \left(\int_0^{s_A} x \, dx + \int_{s_A}^1 (1 - x) \, dx \right) \\
&= y + v_0 + u(q) - s_A F_A - (1 - s_A)(F_B + S) - \frac{\tau}{2} \left(s_A^2 + (1 - s_A)^2 \right).
\end{aligned}
$$

With MNP (where $F_A^{MNP} = F_B^{MNP}$ and $S = 0$) mobile consumers obtain the surplus

$$
CSM^{MNP} = y + v_0 + u(q) - F_A^{MNP} - \frac{\tau}{4}.
$$

In equilibrium, mobile customers are thus strictly better off with MNP iff

$$
\Delta CSM \equiv CSM^{MNP} - CSM = \frac{1}{2} S - \frac{1}{18} \sigma S^2 - \frac{1}{36} \frac{k}{b} (a - bc_T)^2 > 0.
$$

Inspection of ΔCSM indicates that mobile customers are unlikely to benefit from the introduction of MNP when mobile networks are close substitutes (σ is high) and the size of the fixed line telephony is large (k is high).

5.2 IN v. Call-forwarding Solution for MNP

We want to compare the welfare effects of implementing MNP using an IN or a call-forwarding solution. To do so, let $\Delta I \equiv I - I^{CF}$ denote the additional investment costs to move from call-forwarding to an IN solution for implementing MNP. We can then find a critical difference in investment costs, ΔI^*, below (above) which the IN solution yields higher (lower) social welfare. More formally, we have $W^{MNP} > W^{CF}$ for all $\Delta I < \Delta I^*$, where

$$
\Delta I^* \equiv \frac{2}{9} \frac{k}{b} [(a - bc_T)^2 - (a - bc_T^{CF})^2] + \frac{k}{18} [(a - bc_T)^2 - (a - bc_T^{CF})^2].
$$

Straightforward calculations show that ΔI^* increases in the cost differential ($c_T^{CF} - c_T$) and size of fixed telephony market ($\partial \Delta I^* / \partial k > 0$).

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