THE IMPACT OF MOBILE NUMBER PORTABILITY ON PRICE AND CONSUMER WELFARE

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Abstract

This paper examines the effect of Mobile Number Portability (MNP) on market price and consumer surplus. MNP reduces switching costs by allowing consumers to keep their phone number when they change service provider. Most European countries introduced MNP in the early 2000s as a result of a mandate from the European Commission. This supra-national legislative shock provides a unique opportunity to study the relationship between switching costs, price and consumer surplus. Theory shows that market prices can either increase or decrease when switching costs reduce and that followers may try to take advantage of decreasing switching costs to attract consumers from the market leaders. Using quarterly data from 47 wireless service providers in 15 EU countries between 1999 and 2006, we find that MNP decreased market price by at least 4.15% and increased consumer welfare by at least 2.15 euros per person per quarter on average during our period of analysis. This amounts to 880 Million euros per quarter across the 15 EU countries analyzed in this paper and 15% of the observed increase in consumer surplus during the period of analysis. This result is obtained using cost-shifters to instrument changes in price, which allows for determining the demand curve in the markets we analyze. Our study shows how the European experience with regards to the introduction of MNP can be used as an example of best practice by other countries that plan to introduce it in the near future.

1. INTRODUCTION

In a subscription-based market, consumers must generally bear substantial costs to switch from the service provider. When switching costs are sufficiently large, an existing market leader is likely to enjoy a significant advantage that allows him to sustain a large market share (Lieberman and Montgomery 1998; Bijwaard et al. 2008). Therefore, policy makers frequently attempt to reduce switching costs to intensify market competition and increase consumer surplus. However, it is hard to measure the effect of switching costs on consumer surplus and welfare. In fact, the literature on switching costs shows that their effect on market outcomes is complex and sometimes counterintuitive (see Cabral (2012) for more detailed arguments). The conventional belief suggests that when switching costs are present firms are likely to increase price to exploit consumers who are already locked in (Klemperer 1987, 1988, 1995; Beggs and Klemperer 1992). Indeed, a number of empirical studies found that switching costs increase market price (Sharpe 1997; Shy 2002; Stango 2002; Viard 2007). These studies provide evidence that in favor of governmental actions aimed at reducing switching costs. On the other hand, recent literature in marketing and economics (Dubé et al. 2009; Shin et al. 2009; Doganoglu 2010) suggests that with low switching costs firms are not interested in attracting new consumers because they cannot exploit them in the future. Therefore, significantly low switching costs may also result in increased prices, which challenges the prior conventional wisdom.

In essence, understanding the effect of switching costs on market outcomes requires empirical work. The contribution of our paper is exactly to provide empirical evidence of the effect of changes in switching costs on prices and consumer surplus. We use a longitudinal dataset on 47 wireless service providers in 15 European countries over a period of time during which Mobile Number Portability (hereafter MNP) was introduced to reduce market power and

encourage market competition. MNP requires service providers to port phone numbers when consumers change service providers. This, however, may not necessarily benefit consumers. For example, (Aoki and Small 1999) develop a theoretical model showing that the effect of MNP on consumer surplus is ambiguous in developed countries and that only in less developed ones MNP seems to clearly improve welfare essentially through market expansion. The introduction of MNP is a market-level shock (i.e. applies to all providers alike) that reduces switching costs. Thus, it provides an appropriate natural context to evaluate the impact of switching costs on market outcomes. Still, studying how changes in switching costs affect price is a challenging empirical question because a number of unobserved factors correlated to why MNP is introduced may also affect price. This, however, may lead to overestimating the effect of MNP. In this paper, and to alleviate this concern, we study the introduction of MNP in a set of European countries. We study these countries because the European Commission (EC), through *Directive 2002/EC/22*, required them to trigger the necessary legislative processes to introduce MNP in their national markets (European Parliament 2002). It is therefore plausible that none of these countries introduced MNP because of specific market conditions in their own country. We still find that significant variance in how countries were both willing and able to transpose this supra-national directive into national law. Yet, we also show that the time at which MNP was introduced in each country is uncorrelated to relevant country-specific factors, more importantly, price. We show that MNP provisions, namely porting time and porting charge, are also uncorrelated to the time at which MNP was introduced in each country we analyze.

Our paper offers three streams of new results. First, we find that prices declined on average 7.9% due to the introduction of MNP across the countries analyzed in our sample. When controlling for the persistent declining trend in prices over time the effect associated with the

introduction of MNP reduces to 4.15%. These results indicate that a decrease in switching costs leads to a decrease in price, which is in line with the conventional belief described above. Furthermore, we find that policies requiring shorter porting times were also more effective in decreasing price. Second, we show that the effect of the introduction of MNP on price is not different across service providers in the same country. This finding challenges the conjecture that followers may react more elastically to the introduction of MNP so that they can seize the opportunity to steal customers from market leaders. We find that while prices decreased with the introduction of MNP, followers were unable to take advantage of this policy to steal market share from leaders. Finally, we measure the change in consumer surplus associated to the introduction of MNP using the estimate above for how much MNP changed price. We use changes in provider operating costs over time to instrument changes in prices and thus obtain a good approximation of the demand curve for wireless service. Using this 2SLS approach, our findings suggest that, on average, consumer surplus increased at least 2.15 euros per person per quarter (or 880 Million euros per quarter) between the introduction of MNP and the end of 2006 (the end of our panel). This represents about 2.26% of the average ARPU across the countries analyzed in our study before the introduction of MNP. We estimate that 15% of the observed increase in consumer surplus during our period of analysis was due to the introduction of MNP. To the best of our knowledge, our paper is the first study that empirically investigates the effect of MNP on consumer welfare, providing policymakers with a measure of the effectiveness of this policy. In this respect, our analysis adds to the prior literature that studied the impact of MNP on churn rates and prices (Shi et al. 2006; Sánchez and Asimakopoulos 2012; Wei and Zhu 2012).

The remainder of this paper is structured as follows. Section 2 provides background for this study and literature review. Section 3 introduces our data and empirical context. Section 4 presents our empirical models and results obtained. Section 5 provides our approach and findings on consumer welfare. Finally, section 6 discusses our results and concludes.

2. BACKGROUND AND RELATED LITERATURE

The wireless telephony industry grew significantly during the last two decades. In parallel it also underwent several changes in structure, regulation and technology. The telephony market became liberalized in most countries beginning in the 1990s and entrants began to compete more fiercely with monopolists (Büehler et al. 2006). Yet, the wireless telephony industry still exhibits considerable network effects and high switching costs, which lend market leaders significant competitive advantages (Lee et al. 2006). For example, the need to change phone number is one of the most critical hurdles for consumers when switching service providers. Today, callers can be easily identified using caller ID technology, which makes cell phone numbers part of a person's identity. If one cannot port her phone number when changing service providers then one's identity in the mobile world changes over time raising significant personal hassle. More recently, a number of mobile applications use mobile phone numbers as identifiers to connect to social network services (e.g. Whatsapp), so changing phone number when changing service providers may result in momentary loss of connectivity to these services. All of these problems result in additional costs that are most likely borne by consumers alone. This creates market frictions and reduces competitive (Farrell and Klemperer 2007).

National Regulatory Authorities (NRA) for telecommunications adopted MNP as a way to overcome these concerns. MNP requires wireless service providers to offer consumers the

opportunity to keep their phone number when they switch providers. The introduction of MNP can be regarded as a market-level shock that reduces switching costs for consumers. In this regard, MNP pursues two objectives as specified in Büehler et al. (2006): providing a direct benefit to consumers by removing a barrier to switching and providing a fair playing field for competition among firms. However, service providers incur costs to implement MNP (Büehler et al. 2006). These are typically, and in part, passed along to consumers in the form of porting time and porting fee.[1] As such, both this fee and the time to activate MNP have been regulated.

MNP was first adopted in Singapore in 1997.[2] Between 1997 and 2011, 63 other countries have implemented MNP (Pigg and Partridge 2012); in Europe, MNP has been mandated as part of *Directive 2002/EC/22* on Universal Service (European Parliament 2002). This Directive required all EU member states to implement fixed-to-fixed and mobile-to-mobile MNP by July 2003. Some countries, such as the United Kingdom, Spain and Sweden had already introduced MNP prior to this date. Over time, the remaining EU countries complied with this Directive and transposed it into national law. Figure 1 shows the timing of MNP adoption in the fifteen EU countries we analyze in this paper.[3] Austria, Hungary and Poland adopted MNP later than 2003. Austria delayed the introduction of MNP due to the lack of appropriate technical solutions (Büehler et al. 2006) in the country. Hungary and Poland joined the EU in 2004.

(Figure 1 is here.)

Figure 2 shows that there is a large variation across European countries in terms of the percentage of subscribers that ported their phone number when changing wireless provider. For

[1] For example, these include costs that wireless service providers incur to update their routing and billing tables to signal that a particular phone number no longer belongs to the same provider.
[2] MNP in Singapore, however, was only call forwarding, requiring the subscriber to hold two phone numbers at the same time. A more structured process of MNP using a centralized database was introduced in the United Kingdom, Hong Kong, and the Netherlands as early as 1999.
[3] Due to the data available, we select fifteen countries out of the entire EU countries in this study.

example, a sizeable percentage of subscribers ported their number in Finland and Denmark, whereas only 1.4% of consumers did so in Germany and Portugal up to October 2008. We note that consumers do not need to port phone numbers for prices (and consequently consumer surplus) to change. Service providers may simply need to adjust prices because with MNP consumers can more easily change providers. Therefore, the information that Figure 2 conveys may not be enough to discuss the economic effect that the introduction of MNP might have produced in these countries.

(Figure 2 is here.)

MNP has been extensively adopted across Europe. Yet, specific MNP rules and clauses are quite heterogeneous across countries, particularly in what porting time and porting charges are concerned. Porting time refers to period of time between the user's request to change service provider and the activation of the phone number by the new service provider. Porting charge is the one-time fee paid by the consumer to obtain MNP when changing providers. Figure 3 illustrates that porting charges and porting times were indeed different when MNP was first introduced in the countries studied in this paper. Porting time ranges from two months in the Netherlands, to one day in Belgium. Porting charges vary between 40 euros in Portugal to zero euros in countries such as Spain and Denmark. We note that the *Directive 2002/EC/22* did not require countries to enforce specific porting times or porting charges (Büehler et al. 2006). In fact, countries could even refrain from introducing MNP if they showed that the costs to do so would outweigh the benefits.

(Figure 3 is here.)

Firms typically charge different prices to existing consumers and to new consumers in a world with switching costs (Chen 1997). With high switching costs, existing consumers are less

likely to switch; therefore, firms tend to exploit them by charging them high prices. In contrast, firms are likely to compete aggressively for new consumers by lowering their prices or providing them subsidies. Firms do so because they expect to be able to exploit these consumers when they become locked-in, a strategy known as bargain-then-rip off (Klemperer 1987, 1995). However, if switching costs decline, existing consumers are less valuable because they can churn more easily (see section 3 in Viard (2007) for a similar argument). Therefore, firms have less incentive to compete for them in the first place (Dubé et al. 2009; Shin et al. 2009). Therefore, prices can increase when switching costs are significantly low. Therefore, it is unclear whether lowering switching costs reduces average prices because this depends on the mix of new and existing consumers.

While these assertions are well established in the theory, applying them to empirical analysis requires careful thought. It is difficult to observe the prices charged to new consumers and to existing consumers separately, or even the proportion of new to old customers. Instead, one may observe only average prices. However, from the preceding discussion, it is unclear whether the average price decreases or increases when switching costs are reduced. In Appendix A we provide a two-period model to examine the change in equilibrium price as switching costs decrease. This model shows conditions under which average price increases with low switching costs.

A number of studies examine switching costs and network effects in the context of number portability. In fixed telephony, Viard (2007) found that number portability enhances competition in the supply of value-added services, such as toll-free service. More competition, in turn, leads to higher quality of service and to market growth. In mobile telephony, earlier studies compare the impact of differences in MNP provisions across European countries (Büehler et al.

2006) and discuss ways in which regultors can implement MNP to reduce the problems that may arise due to the assymetric information about the best timing and the best technology to do so (Gans and King 2001). Other studies, closer to our paper in nature, study the impact of MNP across countries. Lyons (2006) find that MNP reduces average prices and encourages churn when it requires a short porting time.[4] Sánchez and Asimakopoulos (2012) also show that churn rates are negatively associated to both porting time and porting charges. This suggests that the specific provisions and details of MNP are important to achieve certain policy goals. The country-level analyses performed in these studies do not look at how different service providers within the same country respond to MNP nor they measure the effect of MNP on consumer surplus. Therefore, our analyses in this paper provide additional evidence of the impact of MNP on both providers and consumers, in a way that ultimately regulators care about.

Wei and Zhu (2012) also examine the effect of MNP on market concentration and competition. Their empirical findings suggest that small firms gain market share and that gaps in prices increase along with the share of contract-based customers after MNP. The authors look at the effect of MNP in a wide set of countries, mostly large and developed, between 2003 and 2009. However, many countries in their sample did not introduce MNP during the period of analysis or had already introduced MNP before 2003. These limitations make it hard to interpret the difference-in-difference estimates they report and raise endogeneity concerns, which may bias the results obtained.[5]

[4] This study does not control for porting charges across countries, and the choice of five days as a cutoff seemed to be arbitrary as the author acknowledged.

[5] The authors viewed freedom of speech as instrumental for MNP adoption. However, it may not be plausible that freedom of speech captures unobserved country characteristics that are also correlated with market outcomes (lower prices, more competition etc.). Countries with low freedom of speech may naturally be less competitive countries.

On the contrary, our study looks at a set of countries that were all actively engaged in introducing MNP during our period of analysis. Furthermore, these countries were required by the European Commission to introduce MNP, which we argue acts as an exogenous market-level shock (see section 3.2 for greater detail). While we also study how specific provisions in the introduction of MNP affect market outcomes we go a step further by effectively quantifying how consumer surplus changes due to the introduction of MNP. This is a novelty of our work that the prior literature did not address. Measuring how consumer surplus changes with MNP is a difficult empirical task because one needs to estimate demand. In our paper, we use operating cost-shifters as instruments for price. Operating costs are appropriate instruments to estimate demand because they affect the latter only through prices. Furthermore, in our case, operating cost-shifters are not weak instruments for price allowing us to measure the impact of MNP on consumers in dollar terms.

3. DATA AND EMPIRICAL CONTEXT

3.1. Data Collection and Descriptive Statistics

We use a longitudinal dataset with 47 wireless service providers in 15 European countries from the *Merrill Lynch Global Wireless Matrix* (Merrill Lynch 2004, 2007). Market shares of selected wireless service providers cover almost 100% in each country. The country- and firm-level data contain detailed financial and operational information by quarter, including mobile penetration rate, the number of subscribers, market shares, revenues, prices and mobile voice usage in minutes. Our period of analysis starts in the first quarter of 1999 and ends in the fourth quarter of 2006. All countries analyzed in our sample introduced MNP within this period. Also, during this

period no major new wireless service provider entered any of the markets we analyze nor there was any new regulatory change that could have significantly affected them.[6]

We study the impact of MNP on average price per minute. Fuentelsaz et al. (2012) also used the same strategy to proxy price. Shy (2002) used ARPU, whereas Grajek (2010) used the lowest average customer bill. Other studies, such as Doganoglu and Grzybowski (2004), computed price using information from the structure of the tariff plans offered by carriers. In our study we compute average price per minute dividing average monthly revenue per user (ARPU) by the average monthly Minutes of Usage (MOU). This measure averages out variations across tariff plans and discounts across consumers, providing a true measure of the average per minute experienced in the market. However, note that ARPU generally consists of revenues from voice calls and data services (i.e., SMS and mobile Internet usage). The latter was negligible in the early 2000s but increased considerably during our period of analysis. We discuss how this measurement issue may affect our estimation results in section 4.4.

Figure 4 shows that both ARPU and average price per minute (ARPU/MOU) decreased significantly over time in the 15 countries studied in this paper. ARPU decreased from 40 euros in 1999 to 27 euros in 2006. The average price per minute decreased from 0.31 euros to 0.17 during the same period.

(Figure 4 is here.)

Figure 5 shows price per minute at the firm-level for a subset of the countries in our panel. It is clear that price levels and gaps across wireless service providers within the same country are heterogeneous. This figure also shows that prices declined more sharply after the

[6] The only exception we find is Hutchison 3. Hutchison 3 is a mobile carrier specialized in 3G services that entered the EU market around 2002. However, Hutchison 3's market share was low during our study period, so the effect of this new entrant on major players' competition was limited.

introduction of MNP in some countries (e.g. Finland and Austria) than others (e.g. Germany and Portugal), and thus the effect of the introduction of MNP on price is likely to be heterogeneous.

(Figure 5 is here.)

Summary statistics for the main variables used in this paper are provided in Table 1. The average penetration rate and the number of subscribers are 75% and 21.77 million, respectively, indicating that mobile telephony markets may be close to saturation in some of the countries analyzed in our paper. The average market share of firms is 32%, and thus approximately three service providers serve each country. On average, MNP was introduced in the countries we study approximately in the middle of our period of analysis, between the third and the fourth quarters of 2002. When MNP was introduced, the average porting time and the average porting charges were 15 days and 11 euros, respectively. The variance in these two variables is, however, quite large.

(Table 1 is here.)

3.2. Exogeneity of the Adoption of MNP

Regulators may decide to introduce MNP because of certain market conditions that they aim at improving. Two primary motivations – market drivers and regulatory drivers – can lead to the introduction of MNP (Büehler et al. 2006). In most non-European countries, national regulators adopted MNP to increase competition in their country and thus in these cases the introduction of MNP is likely correlated to fundamental market conditions. However, in the European Union (EU), the European Commission (EC) mandated the introduction of MNP in

March 2002 (with the law coming into effect in July 2003). The specific provision is Article 30 of the Universal Service Directive of 2002, which states

> "*Member States shall ensure that all subscribers to publicly available telephone services, including mobile services, who so request can retain their number(s) independently of the undertaking providing the service: (a) in the case of geographic numbers, at a specific location; and (b) in the case of non-geographic numbers, at any location." (European Parliament 2002)*

Therefore, in the case of the EU, the introduction of MNP was a continent-wide supra-national level decision that the telecommunications regulator in each EU country took as an exogenous legislative shock, thus likely independent of the specific market conditions in each particular country.

Figure 1 shows when EU countries introduced MNP. Seven countries in our panel introduced MNP before March 2002. These countries may have been less affected by the supra-national law referred above. While the EC's mandate was only published in 2002 there was significant discussion and lengthy (~3 years) preparations for this Directive in the years prior to 2002 and thus it is likely that these countries may have simply anticipated the fact that an MNP mandate would pass soon. Even so, it may be that endogenous reasons may have led these set of countries to act in advance. The remaining eight countries in our panel implemented MNP after 2002. In fact, three countries, Austria, Hungary and Poland implemented MNP later than the mandated date. Hungary and Poland joined the EU only in May 2004. Furthermore, Austria and Poland faced technical difficulties to introduce MNP. Büehler et al. (2006) documented that these delays were associated with the lack of proper technical solutions to grant MNP. If the

regulator imposes a very short porting time when technical issues are not resolved (e.g., the central database system of ported numbers is nonexistent), nontrivial difficulties might arise, which in turn may lead to undesirable confusion and prohibitive costs.

We test formally the hypothesis of no correlation between the adoption time of MNP and country characteristics by running Cox proportional hazard regressions (as in Romanosky et al. (2011)). We run several specifications: one is a regression with each explanatory variable at a time – e.g., price, total subscribers, penetration rate and market concentration; the other is a regression with all relevant market variables at once. Table 2 shows the results obtained. We find no correlation between the adoption time of MNP and any of the relevant market characteristics that regulators could seek to change by introducing MNP. This provides empirical evidence in favor of the idea that the EC's mandate was a legislative exogenous shock for each and every country in our panel. Furthermore, we check if MNP features are related to the time at which MNP was introduced by regressing porting time and porting charge on the former. Table 3 presents the results obtained at the country level (recall that the same porting time and porting charge apply to all operators in the same country), showing that both MNP features do not correlate to the time at which MNP was introduced. This provides additional evidence that the time of MNP introduction is exogeneous in the countries studied in this paper.

(Tables 2 and 3 are here.)

4. EMPIRICAL ANALYSIS AND RESULTS

4.1. Effect of MNP on Market Price at the Firm Level

We test whether the introduction of MNP led to a change in prices using firm-level data. For this purpose we use the following reduced form model:

$$\log(price_{imt}) = \alpha + \beta MNP_{mt} + X_{imt}\Gamma + \eta_i + \psi_t + \varepsilon_{imt}, \qquad (1)$$

where log ($price_{imt}$) is the logarithm of the price per minute charged by service provider *i* in country *m* at time *t* and MNP_{mt} is a dummy variable indicating whether country *m* at time *t* had implemented MNP. The latter is the variable of interest in our study that captures the effect of MNP on price. We control for firm- and time-specific fixed effects in η_i and ψ_t, respectively, in order to capture potential unobserved time-invariant firm-specific effects and to control for time trends or seasonal effects on price.

X_{imt} is a vector of firm- and/or country-level controls including lagged market share, total subscribers, penetration rate, GDP per capita and HHI. The prior literature suggests that price is positively correlated with a firm's market power (Klemperer 1995; Chen 1997), measured as market share in our case, and that wireless service providers are likely to decrease price if they expect a sufficiently large number of potential new consumers in the near future – i.e., low market saturation level (Beggs and Klemperer 1992; Viard 2007). One can also anticipate that market concentration, measured using HHI in our case, can be positively correlated with price because a concentrated market towards the incumbent is likely to be less competitive.

We also test the effect of MNP features. To do so we interact them with the introduction of MNP extending our previous model to:

$$\log(price_{imt}) = \alpha + \beta_1 NP_{mt} + \beta_2 NP_{mt} \times PT_m + \beta_3 NP_{mt} \times PC_m + X_{imt}\Gamma + \eta_i + \psi_t + \varepsilon_{imt}, \quad (2)$$

where PT_m and PC_m denote porting time (in days) and porting charge (in euros) in country m. As discussed before (Büehler et al. 2006; Sutherland 2007) it is reasonable to expect the effect of MNP to be weaker when significant barriers to switching remain, such as longer porting time and higher porting charges.

Table 4 presents the results of regressions for Equations (1) and (2) clustering errors at the firm level[7] (Moulton (1986) and Cameron and Miller (2010)). The effect of MNP is negative and statistically significant for all specifications, indicating that market average prices decrease after the introduction of MNP. The coefficient in Column (1) suggests that MNP reduces average price by 8.7% on average. This statistic reduces to 7.9% when we include control variables in Column (2). Columns (3) to (5) present results for the effect of porting time and porting charges. Column (3) indicates that each additional day in the porting time reduces the effect of the introduction of MNP by 0.32%. The effect of the porting charge is not statistically significant in Column (4). Estimates in Column (5) show that porting time is still significant when we include both porting time and porting change in the same regression. Therefore, it appears that porting time is more important than porting charge for the introduction of MNP to trigger a reduction in price. In fact, the EC has more recently (after the end of our panel) amended Directive

[7] Covariates for wireless service providers in the same country are likely correlated. Still, clustering errors at the country level yields similar results (available upon request).

2002/22/EC to reduce porting times, which are now less than two working days in all EU countries.

(Table 4 is here.)

The estimates for the coefficients of the control variables also have interesting implications. For example, market size and market concentration are statistically significant and positively associated to price. In addition, price tends to be lower in more saturated markets because the competition is likely to be fiercer when the number of potential new customers is limited.

4.2. Effect of MNP Across Wireless Service Providers

We examine how different service providers react to the introduction of MNP. Gómez and Maícas (2011) argue that changes in switching costs would have a different effect depending on market positions. For example, high switching costs strengthen the advantage of a first-mover who is able to lock-in consumers and charge them a high price. However, with MNP, a first mover may be more likely to lose consumers, which prevents it from charging such high prices (Bijwaard et al. 2008). If the first-mover charges a lower price with MNP then followers are also likely to charge lower prices to compete. In fact, one may expect followers to decrease price more sharply then first-movers in response to MNP to use its introduction as an opportunity to steal away consumers. We interact a dummy variable indicating the firm rank (rank1 for the market leader and rank2 for the first follower) with the introduction of MNP to check if there are differential effects across service providers. In another regression we use *price range*, measured as the difference in price between the highest and lowest market prices, as a dependent variable

at the country level. If followers reduce price more sharply then the range of prices charged may widen with MNP. Therefore, our models become:

$$\log(price_{imt}) = \alpha + \beta_1 NP_{mt} + \beta_2 NP_{mt} \times rank1_{im} + \beta_3 NP_{mt} \times rank2_{im} + X_{imt}\Gamma + \eta_i + \psi_t + \varepsilon_{imt}, \quad (3)$$

$$price\ range_{mt} = \alpha + \beta NP_{mt} + X_{imt}\Gamma + \eta_m + \psi_t + \varepsilon_{mt}. \quad (4)$$

Table 5 shows the results obtained. Column (1) shows that all providers seem to reduce price similarly. We do not find evidence that followers use the introduction of MNP to decrease price more sharply or, alternatively market leaders decrease their prices as much as followers in order to retain their existing customers. In line with this result column (2) in this table shows that the range of prices charged is not significantly different before and after the introduction of MNP. An aggressive pricing strategy by followers can significantly harm their financial outlook in the long run unless a sufficient number of consumers churn from the market leader. This concern may lead followers to employ more conservative strategies, which seems to be the case in the countries we analyze. Figure 6 shows the price charged by each service provider over time. All providers reduced price by roughly 40% from the beginning to the end of our panel.

(Table 5 is here.)

(Figure 6 is here.)

Robustness Checks

Countries Adopting MNP Before and After EC Directive: As discussed in section 2, seven countries introduced MNP before the EC Directive was introduced. As noted there, some countries may have anticipated this Directive and acted in advance. Table 6 shows that the countries that did so (Group 1: United Kingdom, Netherlands, Switzerland, Spain, Denmark, Sweden, Portugal) are not statistically different from the ones that did not (Group 2: Italy, Germany, Belgium, France, Finland, Austria, Hungary, Poland) in terms of observed relevant market characteristics that regulators could envision to change with the introduction of MNP. More importantly, Table 7 shows regression results for countries in Group 1 and in Group 2 in columns (1) and (2), respectively, and results pooling all countries together and interacting MNP with whether the country introduced MNP before March 2002 in column (3). We find that MNP reduced price similarly in the two sets of countries.

(Tables 6 and 7 are here.)

Short-Term Effect of MNP Introduction: The preceding analysis considered the whole period of data available to us. A concern may arise that over such a long period of time confounding (endogenous) effects may have risen leading to biased estimates of the effect of MNP on price. We now consider only two years of data before and after the introduction of MNP in each country, thus looking at the short-term effect of MNP, as a way to mitigate this concern. Column (1) in Table 8 shows the results obtained. We still find a statistically significant effect of MNP on price although its magnitude halves when considering only such a short period of time. In any case, this result provides additional evidence that indeed the introduction of MNP reduces price.

Adding Time Trends: Figures 4 to 6 show that price has been steadily decreasing over time in all EU countries. One way to account for such a steady decreasing trend in price is to control for it by adding a time trend covariate, such as in:

$$\log(price_{imt}) = \alpha + \beta_1 NP_{mt} + \beta_2 NP_{mt}\times PT_m + \beta_3 NP_{mt}\times PC_m + X_{imt}\Gamma + \eta_i + Trend_t + \varepsilon_{imt}, \quad (5)$$

$$\log(price_{imt}) = \alpha + \beta_1 NP_{mt} + \beta_2 NP_{mt}\times PT_m + \beta_3 NP_{mt}\times PC_m + X_{imt}\Gamma + \eta_i + \psi_t + \eta_i\times Trend_t + \varepsilon_{imt}. \quad (6)$$

The former specification includes a time trend common to all providers whereas the latter allows for this time trend to be different for each provider. Table 8 shows the results obtained for the former specification in columns (2)-(5) and for the latter in columns (6)-(7). As expected the time trend is statistically significant and negative in the first set of columns. The coefficients on the time trends per provider where omitted in the second set of columns for the sake of space. We still find a statistically significant effect of MNP on price, similar to that of column (1). Thus, even adding time trends we still find evidence that indeed the introduction of MNP reduces price.

(Table 8 is here.)

4.3. Lower Bound for the Effect of MNP

In our regressions the dependent variable is average price computed as the ratio of ARPU to MOU. However, while MOU refers to minutes of calls, ARPU typically includes also revenues from data services (i.e., SMS and mobile Internet). From 1999 to 2006, according to Merrill

Lynch data, the contribution of data revenues to ARPU grew from less than 1% to approximately 15%. However, we do not have data to characterize these revenues per country or per provider.

This growth in data revenues may introduce a possible systematic error in our dependent variable. This is the classical problem of measurement error in the dependent variable. In our case, the error is positively correlated with the independent variable of interest. Therefore, this may lead us to underestimate the effect of MNP. Hence, if nothing else, the effects of MNP reported in this paper can be interpreted as lower bounds and thus we can safely say that the introduction of MNP decreased the average price in the set of countries we study.

5. CONSUMER WELFARE

A fundamental topic for policy making is to measure how consumer surplus changes with the introduction of MNP (Hausman et al. 1997; Brynjolfsson et al. 2003; Santerre and Vernon 2006). Figure 7 shows that the increase in consumer surplus associated with the reduction in price due to MNP is the sum of two areas (A and B in the figure). It is not difficult to compute area A given our previous estimates for how MNP reduces price. However, one needs to consider the endogeneity between price and demand in order to estimate area B. We start by assuming that consumption (average monthly minutes of voice) in provider i in country m at time t, represented by q_{imt}, depends on price, represented by p_{imt}, and other market- and firm-level attributes, represented by X_{imt}, such as income (we use GDP per capita as a proxy), number of subscribers (a proxy for network size), lagged market share (a proxy for the firm's market power) and the service penetration rate. Following Hausman et al. (1997) and Dewenter and Haucap (2008), we use the following functional form:

$$\log(q_{imt}) = \alpha \log(p_{imt}) + X_{imt}\Theta + \eta_i + \psi_t + \mu_{imt}. \quad (7)$$

(Figure 7 is here.)

The empirical challenge to estimate Equation (7) is that price is likely related to unobserved covariates that determine consumption. We use average *operating cost per subscriber* as an instrumental variable for price in our setting. Operating cost-shifters have often been used in the literature to instrument price and to obtain consistent estimates of the price elasticity of demand (see Dick (2008) for a case in the banking industry, Neven et al. (2006) for a case in the airline industry, Fell et al. (2014) for a case in the electricity industry). The firm's price is likely positively associated to its operating costs, as Figure 8 shows on average for the operators in our study, but operating costs are unlikely to affect demand except through price.

(Figure 8 is here.)

Table 9 presents the results obtained, including time dummies and firm-fixed effects and clustering errors at the firm level. Column (1) shows OLS results while Column (2) shows the 2SLS results. The first stage regression behaves as expected and is shown in Column (3). Both with OLS and 2SLS the coefficient on price is negative and statistically significant. The price elasticity of demand in Column (2) is roughly -0.92, which is in line with evidence from other studies in mobile telephony (Hausman 1999a, 1999b; Dewenter and Haucap 2008). The coefficients of the control variables are qualitatively similar in OLS and 2SLS and have the expected signs in both cases. Finally, the Kleibergen-Paap rk Wald F statistic shows that our IV

is not a weak instrument (Baum et al. 2007). This is in contrast with other studies in which cost-shifters offer only little variation to help identify the effects of interest (Ackerberg et al. 2007).

(Table 9 is here.)

We follow the approach in Brynjolfsson et al. (2003) to compute the change in consumer surplus associated to the change in price triggered by the introduction of MNP. Let ΔCS denote the compensating variation, which corresponds to the sum of areas A and B in Figure 8, that is:

$$\Delta CS = -\frac{p_1 q_1 - p_0 q_0}{1+\alpha} = -\frac{(1+\phi)p_0(1+\alpha\phi)q_0 - p_0 q_0}{1+\alpha}, \qquad (8)$$

where p_0 (p_1) and q_0 (q_1) represent an average pre- (post-) MNP price and average pre- (post-) MNP monthly minutes of usage, respectively. The derivation of Equation (8) is shown in Appendix B. ϕ relates prices before and after MNP, namely $p_1 = (1+\phi)p_0$. Price decreases with MNP, thus $\phi < 0$ in our case. α denotes the price elasticity of demand, which is also negative, thus $q_1 = (1+\alpha\phi)q_0$ is greater than q_0. In this specification we assume that income elasticity is zero. This is a reasonable assumption widely used in the literature (see Hausman et al. (1997)) because the fraction of the income spent on mobile services is relatively small.

To compute the change in consumer surplus, we plug the estimated price elasticity, the estimated price decrease due to MNP, the pre-MNP average price per minute (0.260 euros) and the pre-MNP average number of minutes used (129.79 minutes) into Equation (5). Using α=-0.9288 and ϕ=-0.0415 (the lowest effect obtained with the random trend model in Column (6) of Table 8) yields that, on average, consumer surplus increased by 2.15 euros per person, or 880 Million euros in the 15 EU countries analyzed, in each quarter after the introduction of MNP (and until the end of our panel). The average ARPU without MNP was 95.13 euros per quarter.

Therefore, the estimated increase in consumer surplus as a percentage of ARPU before the introduction of MNP is 2.26%. The observed average price before and after the introduction of MNP are 0.260 euros and 0.228 euros across our panel, respectively. This corresponds to a 12.3% reduction in price. Therefore, the introduction of MNP was responsible for 33% of the observed reduction in price and for 15% of the observed increase in the consumer surplus during our panel.

6. DISCUSSION AND CONCLUSIONS

This paper analyzes the effect of switching costs in subscription-based markets and studies empirically the case of the introduction of Mobile Number Portability (MNP) in the European Union (EU). MNP requires service providers to port phone numbers when consumers change service providers, thus effectively reducing the costs faced by consumers to switch carriers. In general, consumers in subscription-based markets bear significant costs to switch providers. As a consequence, the market leader is usually able to sustain a large market share, which reduces competition and increases prices. Therefore, policy makers usually regulate these markets and try to reduce switching costs in order to foster competition and increase the well-being of consumers. Historically, researchers have shown that higher switching costs are associated to higher prices. Both theoretical arguments and empirical evidence in this favor have been presented in the literature. However, more recently, researchers have also shown that low switching costs may also lead to higher prices because in this case firms anticipate that they will be unable to exploit consumers in the future (e.g. lock them in) and thus are uninterested in acquiring them in the first place. Setting the appropriate level of switching costs is a complex question and learning about whether decreasing switching costs increases welfare is essentially an empirical exercise.

The contribution of our paper is to exactly provide empirical evidence of the effect that reducing switching costs may have on prices and consumer surplus using the introduction of MNP in the EU as an example. We study these questions using a longitudinal dataset on 47 wireless service providers in 15 EU countries between 1999 and 2006 – that is, over a period of time during which MNP was introduced by the European Commission (EC). One of our major empirical concerns is that the introduction of MNP might have been correlated to unobserved time-varying effects, which would bias our estimate of its effect on price. However, we show strong empirical evidence that the introduction of MNP in this set of 15 EU countries seems unrelated to the specific market conditions in each country included our dataset. Instead, these countries introduced MNP because the EC so decided. This decision by the EC is a supra-national policy shock that required each country to introduce legislation to implement MNP. While there is some variance in terms of when each EU countries introduced MNP, and some countries did so even before the EC formally required them to do so, we find no correlation between the time at which countries in our panel introduced MNP and key market-level statistics that Governments, and the EC itself, would have liked to change with MNP, such as price, subscription rates and market concentration. Finally, we also show that MNP provisions, namely porting time and porting charge, are also uncorrelated to the time at which each country we analyze in our paper introduced MNP.

Our findings are consistent with the idea that the introduction of MNP reduced market prices and increased consumer welfare. Prices declined on average 7.9% due to the introduction of MNP across the countries analyzed in our sample. This statistic becomes 4.15% when we control for the persistent declining trend in prices over time. We also find that shorter porting times were more effective in decreasing prices. In addition, we show that service providers in the

same country did not change prices differently due to the introduction of MNP. This finding challenges the idea that followers may react more elastically to the introduction of MNP to seize the opportunity and steal customers from market leaders. Finally, a major and novel contribution of our paper is to translate these findings to effective changes in consumer surplus. The difficulty in obtaining such a result relies on the fact that one needs to estimate the demand curve to compute the appropriate counterfactuals (for example, what would have happened without MNP). Following a common practice in the literature we use changes in operating costs over time to instrument changes in prices and thus estimate the price elasticity of demand using 2SLS. Changes in operating costs are unlikely to affect demand except through prices. Using this approach and data on operating costs at the provider level, we find that, on average, consumer surplus increased at least 2.15 euros per person per quarter (or 880 Million euros per quarter) between the introduction of MNP and the end of 2006 (the end of our panel). This represents about 2.26% of the average ARPU across the countries analyzed in our study before the introduction of MNP. We estimate that 15% of the observed increase in consumer surplus during our period of analysis was due to the introduction of MNP.

Our analysis goes a step further when compared to those that have only studied the impact of MNP on churn rates and prices. By providing a clear assessment of how the introduction of MNP affects consumer surplus, we provide policymakers with a measure of the effectiveness of this policy, which can be compared to that of other competing policies. Interestingly, our findings also provide support to the decision taken by the EC in early 2009 amending MNP rulings to require even shorter porting times and lower porting charges. In sum, our results provide evidence that the introduction of MNP in Europe was a successful policy tool to increase consumer surplus and thus the European experience in this respect can be seen as an

example of a best practice for other countries that have recently implemented similar policies and are still adjusting some of their parameters (e.g. India) or that have plans to introduce MNP in the near future (e.g. China).

Finally, our study does not come without limitations. For example, we were unable to study heterogeneity in switching costs across users. Different tariff plans incorporate switching costs in different ways but we are unable to exploit this variance in our study to know more about how each consumer takes advantage of MNP due to the lack of reliable operator-specific tariff plan data. We must also be careful when trying to generalize our findings to countries outside the EU. While our results show strong evidence that the introduction of MNP seems to effectively increase consumer surplus the point estimates obtained from our empirical analysis may not apply to other settings and thus the magnitude of the effect that the introduction of MNP may have on prices and consumer surplus elsewhere may be different.

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