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## Conference Paper

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# Deregulating Fixed Voice Services? Empirical Evidence from the European Union\*

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June 9, 2014

## Abstract

This paper deals with the relationship between the traditional fixed-line, mobile and Voice over IP telephony in the EU. We estimate the supply and demand for fixed-line telephony using data on 25 EU member states for the 2006:Q2 - 2011:Q4 period. Employing instrumental variable approach, we obtain the following results. First, lower prices of Voice over IP and mobile reduce the demand for fixed-line telephony. This indicates some demand-side substitution. Second, we find no relationship between Voice over IP and fixed-line prices. Third, there is a positive and significant relationship between mobile and fixed-line prices. Estimated own- and cross-price elasticities are in the inelastic range. Hence, calls to deregulate fixed-line telephony may be too premature.

*JEL-Classification:* C23, L43, L51, L96

*Keywords:* Fixed networks, Mobile services, Market definition, Hypothetical monopolist test, (De)regulation.

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# 1 Introduction

Telecommunications industries were traditionally controlled by state monopolies. Incumbents operated the copper-based public switched telephone networks (PSTN) and provided access to fixed voice services. The last two decades witnessed dramatic changes in the telecommunications sector. Liberalization of the telecommunications markets in 1990s ushered in competition. Alternative operators were allowed to lease the incumbent's infrastructure and provide services to end-users. Widespread deployment of GSM technology and fierce competition in mobile market made mobile services available to large segments of the population. Broadband technologies nowadays include not only the traditional copper, but also cable, fibre, mobile and several other fixed network technologies (WiMaX, satellite). The deployment of broadband technologies paved the way for the development of Internet-based telephony - Voice over IP (VoIP). Managed VoIP provides a service equivalent to fixed-line telephony, while unmanaged VoIP can be used by any broadband subscriber.<sup>1</sup>

Recent market developments raise questions about viability of the traditional telecommunications model. The emergence of new services and intense competition narrowed down the profit margins. The demand for fixed telephone services is declining. Figure 1 indicates a steady decrease in fixed and increase in mobile network traffic in the EU. Further, the number of 'mobile-only' households is rising, although dual access remains relatively common. Managed VoIP telephony is increasingly replacing PSTN (Figure 2). Some operators have even announced plans to switch off the PSTN and implement a full IP-transition (Deutsche Telekom by 2018 and TDC Denmark between 2018-20) (. ECORYS 2013) New entrants are increasing competitive pressures in mobile and broadband market (Figure 3). The emergence of over-the-top applications offering cheap (or free) calls and other services, such as Skype, Viber and WhatsApp, pressured telecom operators even further. These trends have clearly benefited the consumers. However, deteriorating financial position of the main providers may diminish investment incentives. New regulatory designs therefore must maintain a balance between promoting competition and encouraging investment in network infrastructures.

The EU Framework Directive requires the European Commission to adopt and periodically review the Recommendation on relevant electronic product and service markets. The Recommendation identifies markets susceptible to *ex ante* regulation. National regulators are allowed to deviate from the Recommendation if justified by national circumstances. The most recent version (2007) included seven markets, among them access to and call origination on the public telephone network provided at a fixed location (Markets 1/2007 and 2/2007).<sup>2</sup> The Commission

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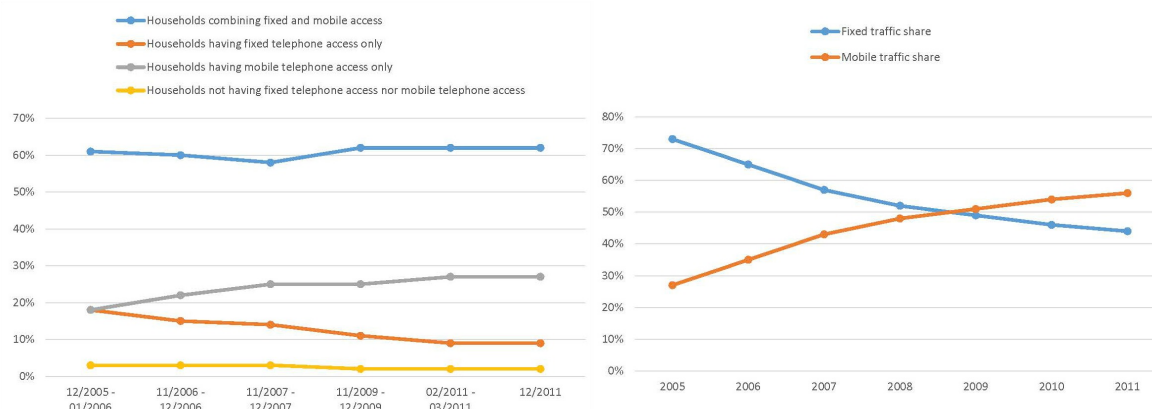
<sup>1</sup> VoIP is a methodology and group of technologies that enables the usage of Internet as the transmission medium for telephone calls. Voice data are being sent in packets using IP rather than by traditional circuit transmissions. Managed VoIP refers to the usage of IP to make and receive phone calls in the standard way (telephone gadget, geographic or non-geographic number assigned), which are then managed by the Internet provider. In the case of unmanaged VoIP, software for making and receiving phone calls is provided by the independent content providers. Typical examples include Skype and Viber.

<sup>2</sup> The remaining five markets include: call termination on individual public telephone networks (PSTN) provided at a fixed location, wholesale physical (network) infrastructure access, wholesale broadband access, wholesale terminating segments of leased lines and voice call termination on mobile networks.

Figure 1: Telephone services in the EU

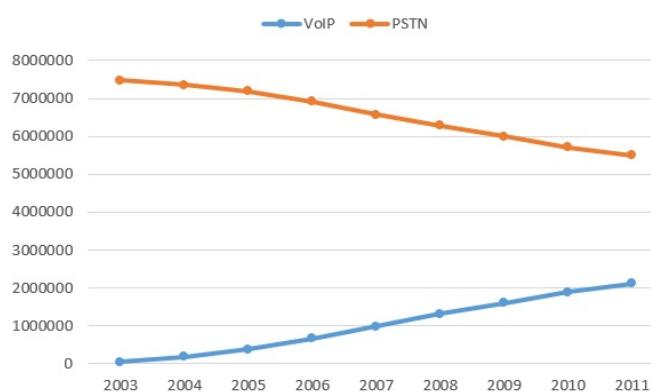
(a) Overall telephone access

(b) Voice traffic on fixed and mobile networks



Source: (a) E-Communications Household Survey 381, (b) Digital Agenda Scoreboard 2013

Figure 2: PSTN and VoIP subscribers, EU average



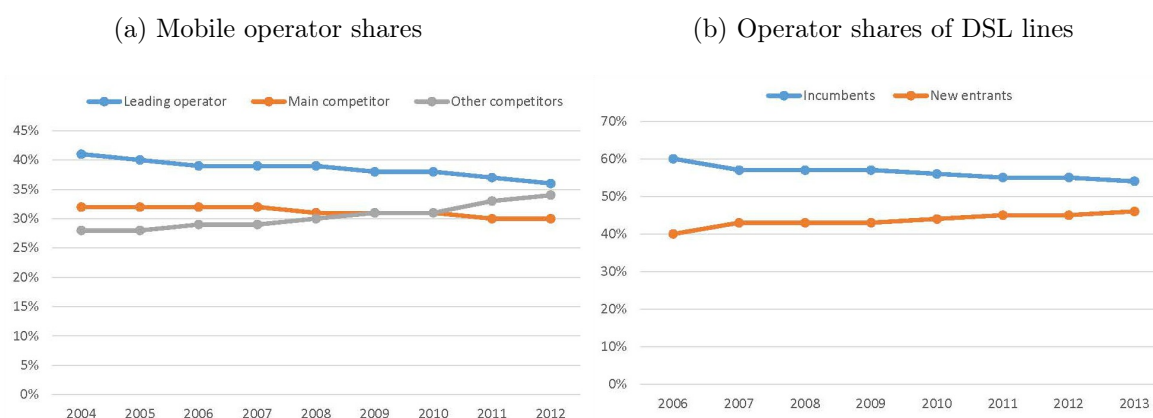
Source: Analysys Mason

substantiates that PSTN providers are relatively insulated from competitive pressures.<sup>3</sup> More recent evidence suggests increased competition in Markets 1/2007 and 2/2007.<sup>4</sup> Managed VoIP providers can reach the end-users relatively easily due to high broadband penetration, widespread deployment of alternative broadband technologies and market entry based on physical network infrastructure and bitstream access. Managed VoIP and PSTN should therefore be treated as part of the same market in countries with high broadband penetration and no possibility of discrimination between consumers with and without access to broadband. Mobile services are not considered substitutable for PSTN, although national regulators may find reasons to conclude

<sup>3</sup> European Commission, Accompanying Document to the Commission Regulation on Relevant Product and Service Markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC of the European Parliament and of the Council on a common regulatory framework for electronic communications networks and services. C(2007)5406. Brussels, 2007.

<sup>4</sup> ECORYS, Future electronic communications market subject to ex ante regulation. Rotterdam, 2013.

Figure 3: Mobile and broadband market shares in the EU



Source: Digital Agenda Scoreboard 2013

otherwise.<sup>5</sup> Hence, *ex ante* remedies such as wholesale line rental and carrier pre-selection (CPS) may be redundant in countries where fixed-line can be easily substituted by managed VoIP or mobile. Deregulation may also have adverse consequences: duopoly of DSL and cable providers, harming socially disadvantaged (who are the most frequent users of CPS services) and captive subscribers (Neumann, Schäfer, Doose & Elixmann 2011). Finally, frequent regulatory changes lead to uncertainty, which may discourage investment.<sup>6</sup> Up to date, Market 1/2007 has been deregulated in Finland and Netherlands only, while UK imposes partial remedies. Market 2/2007 is regulated in all member states.

The issue of PSTN deregulation requires a detailed analysis of the relationship between different types of telephony services. Managed VoIP is usually a cheap add-on to broadband subscription. It has gained a high market share in some countries and is increasingly replacing fixed-lines at the EU-level. However, substitution is not always the result of consumer decisions. Some operators are migrating their PSTN subscribers to IP-networks as part of the underlying business strategy. Voice traffic is increasingly shifting from fixed to mobile networks, although a large share of EU households retains dual access. This may be driven by the underlying broadband technology, since digital subscriber line (DSL) broadband usually comes bundled with fixed voice access. In countries with traditionally underdeveloped fixed line infrastructure and high share of alternative broadband technologies (cable, mobile, fibre), fixed-mobile substitution may be stronger. Another interesting question is the relationship between pricing of PSTN, managed VoIP and mobile services. Providers may not systematically constrain one another even in the presence of strong demand-side substitution. This may be especially true if the operators are active in several markets. In some EU countries, incumbent fixed-line operators are the dominant players in mobile and broadband market. Pricing of fixed-line, managed VoIP and mobile services therefore may not be the result of competitive pressures, but of the operator's strategic behaviour. Hence, strong demand substitution is not an indicator of effective competition.

<sup>5</sup> BEREC, Report on Impact of Fixed-Mobile Substitution in Market Definition. BoR(12)52. 2012.

<sup>6</sup> The Recommendation included 18 markets in 2003 and 7 in 2007, out of which three may be removed this year.

Neglecting this aspect in regulatory decision making process may produce harmful welfare effects.

To the best of our knowledge, only one study (ECORYS 2013) investigates the relationship between PSTN and VoIP at the EU-level. Several studies have examined the diffusion of VoIP and its relationship with PSTN in a single-country framework using consumer-level data (see Cecere & Corrocher (2012), Cecere & Corrocher (2011)). On the other hand, there is a growing body of literature exploring fixed-mobile substitution. Most studies find some substitution between fixed and mobile services, both at the access and at the traffic level (see Rodini, Ward & Woroch (2003), Barth & Heimeshoff (2012*a*), Grzybowski & Verboven (2013)). Fixed-mobile substitution is usually explored in a single-country or aggregate-level framework. Such an approach may not be adequate in the context of EU-policy recommendations, which must recognize country-specific differences. Furthermore, only one study (Grzybowski & Karamti (2010)) addresses the relationship between fixed and mobile prices. This study uses quite old data (up to 2002) and analyzes Germany and France only. There is however no work which investigates the relationship between fixed-line, managed VoIP and mobile services from both demand and supply side in a unified EU cross-country framework.

Our paper aims at closing this research gap. We attempt to answer the following questions: (a) do consumers substitute PSTN with managed VoIP and mobile services, (b) do mobile and managed VoIP services exert a systematic pressure on PSTN pricing, (c) do PSTN and VoIP/mobile voice belong to the same market? We employ a unique dataset for 25 EU countries for the 2006:Q2 - 2011:Q4 period. We estimate our demand and supply model using instrumental variable panel approach. Our main findings can be summarized as follows.

First, there is an evidence of demand-side substitution. Fixed-line subscribers do react to change in price of VoIP and mobile services. Supply-side estimates indicate that PSTN providers set prices independently of managed VoIP, but account for mobile prices and the number of CPS subscribers. These findings have important policy implications: (a) deregulation of Market 1/2007 and 2/2007 based on the assumption of competitive pressure from VoIP is not justified, (b) mobile services constrain the PSTN operators; however, this relationship needs to be examined more closely at the national level, (c) number of CPS users has a significant negative impact on PSTN price. Lifting the regulation may therefore increase the market power of PSTN operators, ultimately harming the remaining subscribers. SSNIP test suggests that estimated elasticities are still below the threshold necessary to justify the deregulation.

The rest of the paper is structured as follows. Section 2 summarizes the existing findings on VoIP demand and fixed-mobile substitution. We attempt to identify gaps in the literature and the contribution of our paper. In the third section, we describe our dataset and empirical specification. Further, we elaborate on market delineation framework. Section 4 discusses the estimation results and defines the relevant market. Section 5 concludes.

## 2 Literature Review

The relationship between fixed-line, managed VoIP and mobile telephony has been insufficiently explored up to date. A growing body of literature summarized in Vogelsang (2010) explores

fixed-mobile substitution. Some substitutability is documented both on access and on traffic level. Recent studies on fixed-mobile substitution account for the impact of broadband penetration. Higher share of incumbent DSL connections is thought to be one of the main drivers of the complementarity between fixed and mobile access, while the spread of cable and mobile broadband increases substitutability. VoIP is a novel technology and insights on its diffusion and the relationship with fixed and mobile services are sparse. Interestingly, almost no study explores the pricing of different types of telecommunications services. Due to a lack of sound empirical evidence, policy recommendations are usually based on a descriptive evidence.

Early studies on fixed-mobile substitution relied on consumer survey data. In one of the pioneering analyses, Ward & Woroch (2004) use the US household survey panel for the 1999-2001 period to estimate the degree of substitution between fixed and mobile services. They find evidence of modest substitutability on the traffic level. Rodini et al. (2003) use the same survey data to explore access substitution in the framework of binary logit model. Estimated cross-price elasticities range between +0.13 and +0.18 for mobile and +0.22 and +0.26 for (second) fixed-line subscription. Ward & Woroch (2010) employs the same dataset to study the demand for mobile access. In line with the previous studies, they find modest substitution between mobile and landline subscription. Briglauer, Schwarz & Zulehner (2011) estimate fixed-mobile substitution in Austria for the 2002-2007 period using aggregate market data. They document relatively strong long-run cross-price elasticity between fixed and mobile calls. Small but significant non-transitory increase in price (SSNIP) test indicates that market for national calls for residential consumers could be deregulated.

Another strand of literature analyzes fixed-mobile substitution in a cross-country framework using aggregate data. Barth & Heimeshoff (2012*a*) study fixed-mobile substitution using a sample of 27 EU member states for the 2003-2009 period. They document strong substitution from mobile to fixed lines. In a related analysis, Barth & Heimeshoff (2012*b*) explore traffic level substitution in the old EU member states. Own-price elasticities of mobile services range between -0.14 and -0.17 in the short run and -0.47 and -0.49 in the long run. Cross-price elasticities of mobile with respect to fixed services are +0.12 in the short and between +0.43 and +0.37 in the long run. More recent studies explore fixed-mobile substitution in the context of Internet access. Grzybowski (2012) finds that higher broadband penetration and share of DSL increase the number of 'fixed + mobile' households in the EU. On the other hand, the spread of cable and 3G increases the share of 'mobile-only' households. This indicates that fixed-line connection may be maintained merely for the purpose of Internet access. In a study using household-level Eurobarometer survey data, Grzybowski & Verboven (2013) finds that (a) there is a strong complementarity between fixed and mobile connections offered by the incumbent, which implies that dominant position in fixed voice market can be leveraged into mobile market, (b) DSL and cable increase complementarity between fixed and mobile telephony, while the penetration of mobile broadband increases substitutability. Suárez & García-Mariñoso (2013) conclude that fixed-mobile substitution in Spain is largely driven by the factors other than price, most notably the type of broadband access, network effects and household's socio-economic characteristics (age and household size).

Few studies analyze issues related to VoIP. Cecere & Corrocher (2012) explore the diffusion of VoIP in Italy on a sample of consumer survey data, finding that IT literacy and higher degree of education are important drivers of VoIP adoption. Furthermore, the use of VoIP is negatively correlated with the usage of other voice communication services, in particular mobile. In another study, Cecere & Corrocher (2011) use the UK consumer survey data, concluding that IT literacy drives the VoIP diffusion. There is some substitution between VoIP and fixed voice; however, no similar relationship is found with respect to mobile services. Finally, this study finds support for the incumbency advantage: incumbent PSTN operators can leverage their dominant position into the VoIP market. Kwak & Lee (2011) find that the adoption of VoIP in South Korea is driven by the three key factors: VoIP call rates, landline call rates and network effects. VoIP is a substitute for PSTN, but does not affect the usage of mobile services. ECORYS (2013) estimates the structural model of substitution between PSTN and VoIP at the aggregate EU-level, concluding that PSTN can probably be deregulated due to a sufficiently large pool of non-captive users. However, we believe that cross-country framework is more appropriate for this type of analysis.

### 3 Estimation strategy and Dataset

#### 3.1 Demand Side

To estimate own- and cross-price elasticities of demand, we specify the following dynamic function:

$$q_{i,t}^{fix} = \alpha_0 + \alpha_1 q_{i,t-1}^{fix} + \alpha_2 p_{i,t}^{fix} + \alpha_3 p_{i,t}^{VoIP} + \alpha_4 p_{i,t}^{mob} + \sum \alpha_k x_{i,t}^k + \gamma_i + \nu_{i,t}, \quad (1)$$

where  $q_{i,t}^{fix}$  denotes the fixed voice demand defined in terms of access, i.e. number of households subscribing to PSTN in country  $i$  at time  $t$ .  $p_{i,t}^{fix}$ ,  $p_{i,t}^{VoIP}$  and  $p_{i,t}^{mob}$  represent the prices of landline, VoIP and mobile telephony, respectively. Vector  $x^k$  includes further explanatory variables: number of households, average annual income per household, Herfindahl-Hirschman-Index (HHI) of intra-platform competition between DSL incumbent and entrants and HHI of inter-platform competition between DSL, cable and other fixed broadband technologies. Hence,  $x = [house, income, HHI^{intra}, HHI^{inter}]$ . Country fixed effects are captured by  $\gamma_i$ , while  $\nu_{i,t}$  is an unobserved error term. We rewrite the equation (1) as follows:

$$q_{i,t}^{fix} = \alpha_0 + \alpha_1 q_{i,t-1}^{fix} + \alpha_2 p_{i,t}^{fix} + \alpha_3 p_{i,t}^{VoIP} + \alpha_4 p_{i,t}^{mob} + \alpha_5 house_{i,t} + \alpha_6 income_{i,t} + \alpha_7 HHI_{i,t}^{intra} + \alpha_8 HHI_{i,t}^{inter} + \gamma_i + \nu_{i,t}. \quad (2)$$

In order to avoid spurious correlations, we test for the presence of unit root. Dependent variable follows I(0) process, which implies stationarity. Therefore, equation (2) can be estimated in levels. We expect negative own- and positive cross-price elasticities for both VoIP and mobile voice. Given the fact that VoIP is still an emerging technology, cross-price elasticity of mobile is expected to be higher, i.e.  $|\eta_{ff}| > \eta_{fm} > \eta_{fv} > 0$ , with  $\eta_{ff} = \frac{\partial q_f}{\partial p_f} \frac{p_f}{q_f}$  and  $\eta_{fj} = \frac{\partial q_f}{\partial p_j} \frac{p_j}{q_f}$ .  $f$  and  $j = \{V, m\}$  denote fixed-line, VoIP and mobile respectively.



Estimation procedure must account for several potential sources of endogeneity. First, the lagged dependent variable  $q_{i,t-1}^{fix}$  is correlated with the error term due to spillovers of past demand shocks into the current period. Second, price and demand are determined simultaneously, which creates an identification problem. Third,  $HHI^{inter}$  and  $HHI^{intra}$  could be endogenous because higher demand affects the decision to enter the market, whereas more market entry decreases the price and drives demand upwards. Fourth, quality advancements in VoIP and mobile services (e.g. longer battery life, more stable broadband connections, enhanced sound quality due to improved speakers and microphones, the advent of smartphones) resulted in positive unobservable demand shocks, simultaneously lowering the demand for PSTN. Hence,  $p_{i,t}^{VoIP}$  and  $p_{i,t}^{mob}$  are endogenous due to correlation with unobserved effect  $\nu_{it}$ . Furthermore, unobserved country-specific fixed effects, such as state aid and regulation impact the efficiency of operators, market structure and market outcome. We therefore estimate the demand for PSTN using the within-estimator.

To remedy for the endogeneity problem, we need instruments which meet the following criteria: (a) relevance, i.e. high correlation with the endogenous explanatory variable, (b) exogeneity, i.e. zero correlation with the error term. We instrument lagged dependent variable, prices and market structure variables with their own lags. In addition, prices are instrumented with cost shifters, which are regularly used in the empirical literature. These are the variables which determine prices, but do not directly affect demand. As cost shifters, we employ fixed-to-fixed and fixed-to-mobile termination rates. They are exogenously set by the national regulators. Further, we use the number of unbundled local loops and population density. The former variable has a direct effect on the cost structure of incumbent PSTN providers. Population density determines the cost of infrastructure deployment and maintenance: serving densely populated areas is usually cheaper than serving sparsely populated ones. Moreover, these variables vary across the countries. We further employ the average fixed voice price in the neighboring countries as an instrument for  $p_{i,t}^{fix}$ . This is an adequate proxy because common shocks affect all prices in the region in the same manner, but do not directly impact demand in the country of interest.

In order to evaluate the bias induced by the presence of endogeneity, the demand equation is estimated using fixed effects (FE) and instrumental variable fixed effects (FEIV) approach. Our results are presented in Section 4.

## 3.2 Supply Side

In addition to the demand, we estimate the supply of PSTN services. The decision whether to deregulate PSTN should be based on a sound market definition. For this end, supply-side substitution between the relevant services needs to be evaluated. We test for the observable change in wireline price in response to change of VoIP and mobile telephony prices. Supply side is represented by the function  $p_{i,t}^{fix}(MC_{i,t}, Y_{i,t})$ , where  $p_{i,t}^{fix}$  represents the price of fixed voice in country  $i$  at time  $t$ ,  $MC_{i,t}$  incorporates marginal cost factors and  $Y_{i,t}$  all other explanatory variables. We estimate the following model:

$$\begin{aligned}
p_{i,t}^{fix} = & \beta_0 + \beta_1 p_{i,t}^{VoIP} + \beta_2 p_{i,t}^{mob} + \beta_3 q_{i,t-1}^{fix} + \beta_4 cps_{i,t-1} + \beta_5 HHI_{i,t}^{inter} + \beta_6 HHI_{i,t}^{intra} \\
& + \beta_7 ftf_{i,t} + \beta_8 ftm_{i,t} + \beta_9 bond_{i,t-1} + trend + \eta_i + \mu_{i,t},
\end{aligned} \tag{3}$$

where  $p_{i,t}^{VoIP}$  and  $p_{i,t}^{mob}$  denote the prices of VoIP services and mobile telephony. The installed base is given by  $q_{i,t-1}^{fix}$ , while  $cps_{i,t-1}$  accounts for the number of carrier pre-select subscribers.  $HHI_{i,t}^{intra}$  and  $HHI_{i,t}^{inter}$  represent the Herfindahl-Hirschman indices of intra- and intermodal competition. Marginal cost factors include fixed-to-fixed and fixed-to-mobile termination rates given by  $ftf_{i,t-1}$  and  $ftm_{i,t-1}$ . Further, we include the cost of capital proxied by the 3-month interest rate (variable  $bond_{i,t}$ ). We employ its first lag due to the fact that change in capital costs cannot be passed on consumers immediately. Finally, linear time trend which captures quality improvements, i.e. service quality, overall network performance, decrease in prices is included (cf. Grzybowski 2005). Country-fixed effects are captured by  $\eta_i$ , while  $\mu_{i,t}$  represents an unobserved error term. Fixed effects approach remedies for the endogeneity arising from country-specific factors. However, for the same reasons as in the demand equation, we have to instrument potentially endogenous variables: prices of VoIP and mobile voice and competition variables. These variables are instrumented with their own lags and population density. Equation (3.2) is estimated with FE and FEIV procedure, results are presented in Section 4.

### 3.3 SSNIP Test

The Small but significant non-transitory increase in prices (SSNIP) test is a well-established market delineation approach. SSNIP test identifies the smallest relevant market within which a hypothetical monopolist could profitably raise its price without consumers turning to alternative suppliers. Small but significant price increase is usually interpreted at 5-10%, while non-transitory is interpreted as a period of 1-2 years (Briglaier et al. (2011)). In practice, SSNIP test is usually based on the estimation of own- and cross-price elasticities. In order to define the relevant market, estimated cross-price elasticities are compared to the so-called critical elasticity  $\epsilon_c$ . Critical elasticity can be calculated by making explicit assumptions on demand function and marginal cost. Briglaier et al. (2011) show that, under the assumptions of constant marginal cost and log-linear demand, critical elasticity is  $\epsilon_c = [\log(m+t) - \log(m)] / \log(1+t)$ , where  $m = \frac{p-c}{p}$  denotes the price-cost margin and  $t$  is the assumed price increase. In the case of linear demand, the formula for critical elasticity is  $\epsilon_c = 1 / [m+t]$ .

### 3.4 Data

We employ the unbalanced panel dataset comprising 25 EU countries for the 2006:Q2 - 2011:Q4 period.<sup>7</sup> Our data is of biannual frequency. Subscription and price data are obtained from the Analysys Mason's 'Telecoms Market Matrices' and 'Triple-play pricing study'. Socio-economic variables and cost factors (except of termination rates) are retrieved from Eurostat, while fixed-to-fixed and fixed-to-mobile termination rates come from 'Progress Reports on Single European Electronic Communications Markets'.

Table 1 provides a descriptive statistics of our dataset.<sup>8</sup> Variable  $q^{fix}$  represents the fixed

<sup>7</sup> The dataset comprises: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK.

<sup>8</sup> Detailed description of all the variables can be found in the Appendix.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
$q^{fix}$	14.897	1.222	12.66	17.192	300
$p^{fix}$	3.801	0.339	2.58	4.564	298
$p^{mob}$	3.124	0.38	2.1	3.913	300
$p^{VoIP}$	3.845	0.333	2.349	4.351	192
$HHI^{inter}$	0.570	0.194	0.352	0.998	300
$HHI^{intra}$	0.76	0.176	0.5	1	300
$csp$	12.753	1.892	8.006	16.535	297
$income$	-4.514	0.622	-6.149	-3.441	298
$house$	15.277	1.136	13.258	17.519	300
$pop_{den}$	4.557	0.771	2.851	6.204	298
$ftf$	-0.147	0.676	-4.605	1.253	272
$ftm$	2.057	0.453	0.698	2.935	282
$bond$	0.984	0.775	-0.713	2.776	300
$trend$	6.5	3.458	1	12	300

voice demand defined in terms of access, i.e. number of households subscribing to PSTN in each country.  $p^{fix}$  denotes the average monthly bill of a typical PSTN subscriber. This variable must be constructed in such a way to account for two types of PSTN subscribers: those using PSTN only and those subscribing to both PSTN and broadband (either as the stand-alone services or bundles). We construct  $p_{i,t}^{fix}$  as the weighted average of PSTN bill and broadband bill of a typical user. PSTN bill is calculated as the average revenue per line (including access and call charges). Broadband bill of a typical user is provided by the Analysys Mason. Weight assigned to broadband bill is the percentage of population with Internet, but no VoIP access. The construction of  $p_{i,t}^{fix}$  as the combination of PSTN and broadband price is done in order to ensure comparability with the prices of VoIP services. Namely, VoIP is in most cases bundled with broadband and making a distinction between ‘pure’ VoIP and broadband price would be difficult. Furthermore, fixed-line users with and without access to Internet have different cross-price elasticities for VoIP services. Hence, in order to subscribe to VoIP, PSTN-only users would have to purchase broadband access first. For users with dual access, the decision to switch to VoIP does not entail high additional costs. In order to make wireline and VoIP services comparable, we have to consider the total communication service bill instead of stand-alone PSTN price.

$p_{i,t}^{mob}$  and  $p_{i,t}^{VoIP}$  denote the prices of mobile and VoIP telephony.  $p_{i,t}^{mob}$  is calculated as the average revenue per subscriber (ARPU) on a country level. ARPU can be interpreted as the average monthly bill for mobile telephony. Subscription cost for VoIP service  $p_{i,t}^{VoIP}$  is a monthly bill of the ‘typical’ user purchasing bundle of broadband and VoIP. The variable  $csp_{i,t}$  stands for the number of subscribers using carrier pre-selection (CPS) telephony.  $HHI_{i,t}^{intra}$  is calculated as the sum of squared market shares of DSL incumbent and local loop- or bitstream-based entrants.  $HHI_{i,t}^{inter}$  represents the sum of squared market shares of DSL broadband, cable and other types of fixed broadband. Variable  $house_{i,t}$  is retrieved from Eurostat and represents the total number

of households in a country. Variable  $income_{i,t}$  is constructed as the country-level GDP divided by the number of households. All variables are expressed as logarithms in order to interpret them as elasticities. Prices are deflated using the corresponding consumer price index for each country.

## 4 Results

Table 2 reports the results of FE and FEIV estimation. We test for the quality of instruments by applying Hansen's  $J$  statistics, underidentification and Hausman test (Hausman 1978). All three tests confirm the validity of instruments. Hence, coefficients from FEIV regression are expected to be unbiased.

Coefficients from the demand equation have expected signs. Installed base and weaker intramodal competition have positive and significant (1% and 5% level, respectively) effects on the number of PSTN subscribers. Lower degree of intramodal competition, indicated by a higher HHI, is usually due to the dominance of incumbent copper operator in the provision of DSL service. Since the incumbents often sell PSTN and DSL bundled together, less strenuous intramodal competition may discourage PSTN disconnections. Number of households as a proxy for market size, income per household and lower degree of intermodal competition have expected positive signs, but neither is significant. Estimated own-price elasticity of PSTN services is -0.223 (1% significance level). Cross-price elasticities of mobile and VoIP services are 0.102 and 0.042 (5% significance level). Hence, 1% increase in PSTN price triggers a 0.223% decline in subscriptions. The same decrease in price of VoIP and mobile services decreases demand for PSTN services by 0.102% and 0.042%. Cross-price elasticities are ranked as expected:  $|\eta_{ff}| > \eta_{fm} > \eta_{fV} > 0$ , where  $f$ ,  $m$ , and  $V$  represent PSTN, mobile and VoIP. Estimated own- and cross-price elasticities are of a similar or even higher magnitude compared to previous studies. The reason behind may be the actuality of our dataset. Overall, the results indicate substitutability between PSTN and other types of telephony. Consumers substitute their fixed lines with mobile, but also with the emerging Internet-based telephony.

Estimated effects of marginal cost and demand factors from the supply equation are in line with the economic theory. Higher installed base and cost of capital increase the PSTN price. A 1% increase in the previous-period number of subscribers results in 0.548% price increase, while the same increase in cost of capital produces 0.027% price increase. Surprisingly, termination rates are not significant. This may be due to their steady decline and the corresponding lower impact on pricing. Similarly as in the demand equation, lower degree of intramodal competition enables PSTN providers to set higher prices. Higher DSL incumbent market share can lead to increased price of telephony-broadband bundles because the competitive pressure from entrants is weak. Increased usage of carrier pre-select services exerts price pressure on PSTN incumbents. Furthermore, PSTN price is strongly affected by mobile but not VoIP price. 1% decline in mobile price lowers the price of PSTN by 0.51%. This implies that PSTN price increase may not be possible without losing a share of consumers to mobile services. However, no similar relationship between VoIP and PSTN prices has been found. This may be due to the fact that VoIP is still

Table 2: Estimation results

Dependent Variable:	<i>Demand</i>		<i>Supply</i>	
	$q_{i,t}^{fix}$		$p_{i,t}^{fix}$	
	FE	FEIV	FE	FEIV
$p_{i,t}^{fix}$	-0.018 (0.02)	-0.223*** (0.080)	- -	- -
$p_{i,t}^{VolP}$	0.005 (0.008)	0.042** (0.020)	0.022 (0.041)	-0.104 (0.085)
$p_{i,t}^{mob}$	0.025 (0.021)	0.102** (0.041)	0.514*** (0.124)	0.511** (0.220)
$q_{i,t-1}^{fix}$	0.960*** (0.023)	0.971*** (0.037)	0.343 (0.214)	0.548*** (0.179)
$cps_{i,t-1}$	- -	- -	-0.071* (0.038)	-0.086** (0.031)
$HHI^{inter_{i,t}}$	0.109 (0.073)	0.136 (0.101)	0.383 (0.450)	-0.009 (0.980)
$HHI^{intra_{i,t}}$	0.024 (0.041)	0.154** (0.074)	0.157 (0.213)	0.700*** (0.237)
$income_{i,t}$	0.021 (0.029)	0.013 (0.043)	- -	- -
$house_{i,t}$	0.037 (0.231)	0.680 (0.448)	- -	- -
$ftf_{i,t}$	- -	- -	0.018 (0.012)	0.004 (0.012)
$ftm_{i,t}$	- -	- -	-0.047 (0.047)	-0.038 (0.042)
$bond_{i,t-1}$	- -	- -	0.025* (0.013)	0.027*** (0.001)
$trend$	- -	- -	0.027** (0.012)	0.027** (0.012)
Intercept	-0.011 (3.850)	- -	-2.518 (3.476)	- -
N	192	138	183	152
R <sup>2</sup>	0.971	0.973	0.295	0.169
F	676.7	667.0	2.893	2.48
Hansen's j $\chi^2$		6.910		1.539
Underidentification		16.308***		12.428***
Hausman $\chi^2$		15.87**		17.39*

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%.

Heteroskedasticity robust standard errors are reported in parentheses.

P-values are reported in squared brackets.

an emerging technology, which is usually provided as add-on to broadband. For PSTN users without Internet access, this would imply high switching costs. To sum up, the demand-side substitution between different types of telephony does not seem to reflect on the supply-side. The consumers do substitute from PSTN to mobile and VoIP; however, PSTN operators' price setting decisions are not affected by VoIP prices.

We apply SSNIP test to decide whether PSTN and other types of telephony services belong to the same market. Critical elasticity is calculated as described in subsection 4.3. Our demand function is in log-linear form. Furthermore, we assume constant marginal cost. Following Briglauer et al. (2011), we assume 75% price-cost margin. With 5-10% price increase, critical elasticities are in range  $\epsilon_c \in [-1.25, -1.18]$ . The estimated cross-price elasticities are far below this threshold. Hence, neither VoIP nor mobile seem to be in the same market with PSTN at the EU-level. This issue must be explored more closely by each national regulatory authority, because country-level competitive conditions may be such as to justify the deregulation.

## 5 Conclusion

This study investigated the patterns of substitution between PSTN, VoIP and mobile voice services. Using a unique dataset on 25 EU countries for the 2006:Q2 - 2011:Q4 period and applying dynamic estimation techniques, we obtain the following estimation results. First, consumers perceive VoIP and mobile telephony as substitutes for the traditional fixed-line. Estimated own-price elasticity for PSTN is -0.223, while the cross-price elasticities with respect to VoIP and mobile prices are 0.042 and 0.102, respectively. Second, installed base and lower degree of intramodal competition have a positive significant effect on the current number of subscribers. Third, PSTN operators set prices independently of VoIP services, but account for mobile prices. Fourth, PSTN price decreases with an increasing number of carrier pre-select users. In a nutshell, traditional fixed-line telephony is being replaced with mobile and VoIP services, although only mobile seems to restrict fixed-line providers in their price setting.

The results of our analysis have important policy implications. First, although some substitution between PSTN and VoIP is found on the demand side, supply side estimates do not support the conclusion that VoIP services constrain the market power of PSTN operators. Some studies suggest that Markets 1/2007 and 2/2007 may be deregulated due to competitive pressure from VoIP. Our results suggest that such a view may not be justified. Second, both demand- and supply-side estimates indicate that mobile services constrain the market power of PSTN operators. The Commission and most national regulatory authorities dismiss this notion, arguing that PSTN and mobile services are not comparable due to different functionalities, subscription and usage patterns. However, this relationship needs to be carefully examined at the national level. As an example, Finnish regulator (FICORA) has already deregulated PSTN access market due to strong substitution between fixed and mobile services. Finally, given that the number of carrier pre-select users has a clear price-decreasing effect, potential implications of lifting the deregulation need to be carefully examined. This becomes even more relevant given that carrier pre-select users are generally found among socially disadvantaged groups. In the case of deregu-

lation, national authorities must ensure reasonable terms of use for captive users, i.e. subscribers who cannot give up on their fixed-line connection. Depending on the size of captive group, dominant PSTN operator should remain subject to appropriate obligations.

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# Appendix

Table 3: Variable description and source

Variable	Description	Source
$q^{fix}$	Number of PSTN subscribers.	Analysys Mason (Market Matrix)
$p^{fix}$	Weighted average of PSTN bill and broadband bill of a typical user, calculated as the average revenue per line including access and call charges (in EUR PPP).	Analysys Mason (Market Matrix)
$p^{mob}$	Monthly subscription for mobile telephony (in EUR PPP).	Analysys Mason (Market Matrix)
$p^{VoIP}$	Monthly subscription for a broadband tariff solely bundled with VoIP (in EUR PPP).	Analysys Mason (Triple-play pricing study)
$cps$	Number of subscribers using carrier pre-selection.	Analysys Mason (Market Matrix)
$HHI_{inter}$	Herfindahl-Hirschman-Index (HHI) for inter-platform competition between DSL and cable market shares.	Analysys Mason (Market Matrix)
$HHI_{intra}$	Herfindahl-Hirschman-Index (HHI) for intra-modal competition between entrants' market share and the DSL incumbent' market share.	Analysys Mason (Market Matrix)
$income$	Annual income per household (in EUR PPP).	Eurostat
$house$	Number of households.	Eurostat
$pop_{den}$	Population density.	Eurostat
$ftf$	Fixed-to-fixed termination rates (in EUR PPP).	Progress Reports on Single European Electronic Communications Markets
$ftm$	Fixed-to-mobile termination rates (in EUR PPP).	Progress Reports on Single European Electronic Communications Markets
$bond$	3-month money market interest rates (in EUR PPP).	Eurostat