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

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## Abstract

This paper analyzes the relationship between the traditional fixed-line, mobile and Voice over IP (VoIP) telephony in the EU. In doing so, it aims at filling the gap in the empirical literature on the substitution patterns between these technologies in a comprehensive way. It relies on demand estimation for fixed-line telephony using a unique data set comprising 25 EU member states for the 2006:Q2 - 2011:Q4 period. Employing instrumental variable approach, demand-side substitution for VoIP as well as mobile telephony services is found to be prevalent. Estimated short-run own- and cross-price elasticities are in the inelastic range, however, in the long run demand is clearly elastic. Hence, our results underpin the Europeans Commission's current decision to lift the ex ante regulation on the fixed-line telephony market.

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

*Keywords:* Fixed networks, Mobile services, Market definition, (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. At the turn of the century, widespread deployment of GSM technology and fierce competition in mobile market made mobile services available to large segments of the population, giving rise to fixed-line disconnections. Moreover, the roll-out and take-up of different broadband technologies perpetuated this process. 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 on both access and usage level. As Figure 1 indicates the number of 'mobile-only' households is steadily rising in the EU, although dual access remains relatively common (especially, in Western European countries). Moreover, a steady decrease in fixed and increase in mobile network traffic is observable. In general, new entrants are increasing competitive pressures on incumbents in mobile and broadband market (Figure 2). Regarding the relationship between PSTN and VoIP telephony strong substitution patterns are depicted in Figure 3. Some operators, e.g. Deutsche Telekom AG and TDC Denmark, have even announced plans to switch off the PSTN and implement a full IP-transition until 2020 (cf. ECORYS 2013). 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. Regulatory designs therefore must maintain a balance between promoting competition and encouraging investment in network infrastructures.

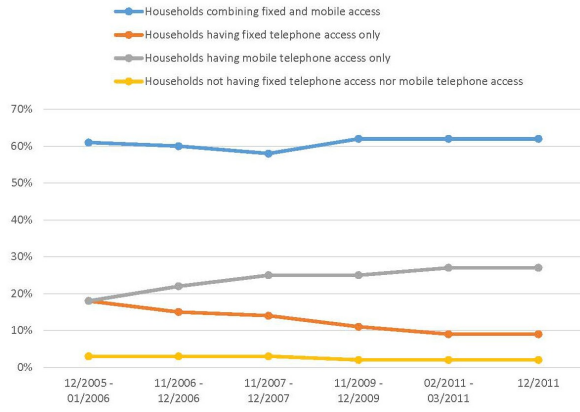
The EU Framework Directive requires the European Commission to adopt and periodically review the Recommendation on relevant electronic product and service markets. The Recommendation identifies markets susceptible to ex ante regulation. National regulators are allowed to deviate from the Recommendation if justified by national circumstances. The Commission

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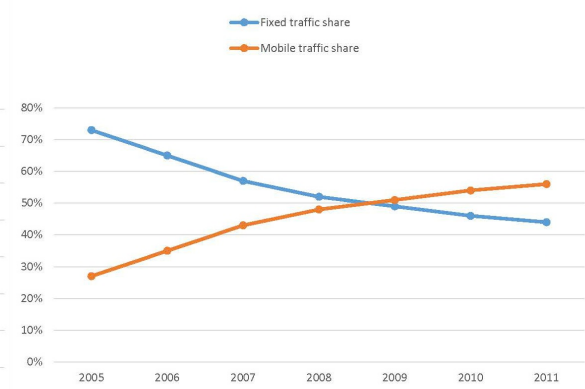
<sup>1</sup>VoIP is a methodology and group of technologies that enables the usage of Internet as the transmission medium for telephone calls. Voice data are being sent in packets using IP rather than by traditional circuit transmissions. Managed VoIP refers to the usage of IP to make and receive phone 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.

Figure 1: Telephone services in the EU

(a) Overall telephone access



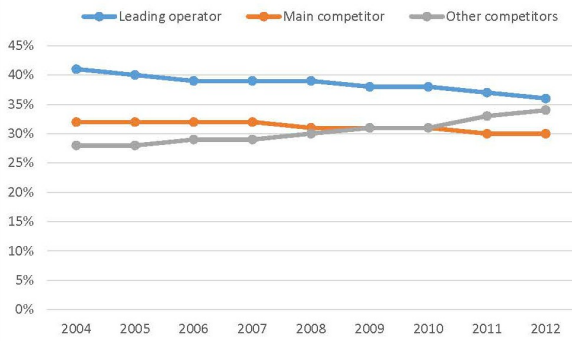
(b) Voice traffic on fixed and mobile networks



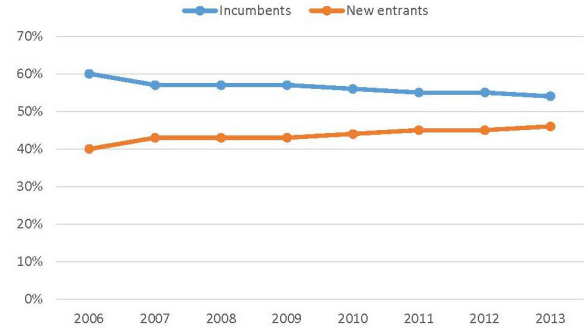
Source: (a) E-Communications Household Survey 381, (b) Digital Agenda Scoreboard 2013

Figure 2: Mobile and broadband market shares in the EU

(a) Mobile operator shares



(b) Operator shares of DSL lines



Source: Digital Agenda Scoreboard 2013

formerly substantiated that PSTN providers are relatively insulated from competitive pressures.<sup>2</sup> More recent evidence suggests increased competition in Markets 1/2007 and 2/2007.<sup>3</sup> The most recent version from October 2014 excludes the markets on access to and call origination on the public telephone network provided at a fixed location (Markets 1/2007 and 2/2007) from the list.<sup>4</sup> Up to date, Market 1/2007 has been already deregulated in Finland and Netherlands, while UK imposes partial remedies. Market 2/2007 was regulated in all member states. In total four markets are still regarded as susceptible to ex ante regulation<sup>5</sup> The change in regulation is

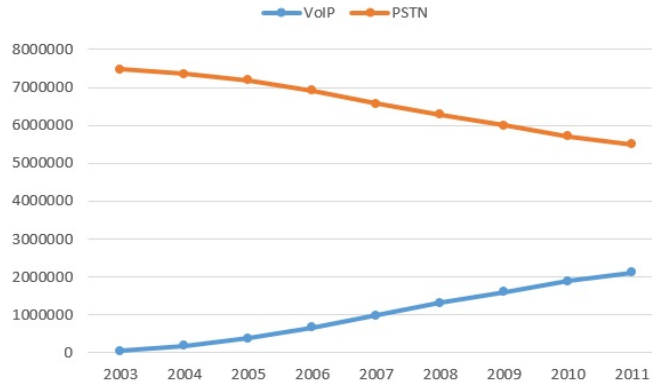
<sup>2</sup>European Commission (2007).

<sup>3</sup>ECORYS (2013).

<sup>4</sup>European Commission (2014a).

<sup>5</sup>The remaining markets include: Market 1/2014: Wholesale call termination on individual public telephone networks provided at a fixed location; Market 2/2014: Wholesale voice call termination on individual mobile networks; Market 3/2014: a) Wholesale local access provided at a fixed location, b) Wholesale central access provided at a fixed location for mass market products; Market 4/2014: Wholesale high-quality access provided at a fixed location.

Figure 3: PSTN and VoIP subscribers, EU average



Source: Analysys Mason

justified by sufficient competitive pressure exerted by VoIP services. 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 are therefore 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. In contrast, mobile services are not considered substitutable for PSTN. However, it is acknowledged that “[...] mobile may exert pressure on fixed to the extent that fixed operators are constraint in their price setting, which then should be duly taken into account [...]” (European Commission 2014b, p. 22). 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. Nevertheless, intended deregulation may also have adverse consequences: a duopoly of DSL and cable providers might harm the socially disadvantaged (who are the most frequent users of CPS services) and captive subscribers (Neumann, Schäfer, Doose & Elixmann 2011).

The issue of PSTN deregulation requires a detailed analysis of the relationship between different types of telephony services. First, 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. Notwithstanding, 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. Second, voice traffic is increasingly shifting from fixed to mobile networks, although a large share of EU households retains dual access. Thus, traffic substitution might be more pronounced than access substitution. 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. The relationship between PSTN, managed VoIP and mobile services are quite complex, since providers may not systematically constrain one another 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. Thus, pricing of fixed-line, managed VoIP and mobile services may not be the result of competitive pressures, but of the operator's strategic behavior. Neglecting this aspect in regulatory decision making process may produce harmful welfare effects.

As a consequence, the relationship between PSTN, managed VoIP and mobile services has to be analyzed in a combined framework which, to the best of our knowledge, has not been done before. Some studies have examined the diffusion of VoIP and its relationship with PSTN in a single-country framework using consumer-level data (see Cecere & Corrocher 2011, Ida & Sato 2008). As far as we are aware, only ECORYS (2013) investigates the relationship between PSTN and VoIP at the EU-level. Furthermore, only scarce empirical evidence exists about the relationship between VoIP and mobile communication services (Cecere & Corrocher 2012). 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 2014a, 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.

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, and (c) do PSTN and VoIP/mobile voice belong to the same market? Ignoring one or another of these two potential substitutes might lead to biased results concerning the estimated elasticities. We employ a unique dataset for 25 EU countries for the 2006:Q2 - 2011:Q4 period, enabling us to account for recent developments which have been largely neglected in the empirical literature. We estimate a demand model using dynamic panel instrumental variable approach. We are able to utilize detailed price information, which is another strength of this paper. Our main finding is that there is evidence of sufficient demand-side substitution, especially in the long-run. Fixed-line subscribers do react to change in price of VoIP and mobile services. Although the European Commission bases its decision on the substitution between PSTN and VoIP, we observe that mobile operators constrain the PSTN operators to a larger degree. In a nutshell, from a forward-looking perspective deregulation of Markets 1/2007 and 2/2007 based on the assumption of competitive pressure from (i) VoIP and (ii) mobile services is justified.

The remainder 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, the empirical specification and discusses the estimation results. Finally, Section 4 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 nicely 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, since PSTN is sold within a bundle. Consequently, the spread of cable and mobile broadband are found to increase substitutability. VoIP is a novel technology and insights on its diffusion and the relationship with fixed and mobile services are sparse. Further, almost no study explores the pricing of different types of telecommunications services, owed to lack of reliable pricing data. In the absence 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) employ the same data set again 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 (2014a) study fixed-mobile access 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 (2014b) 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 (2014) 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) find 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. There is evidence for substitution between PSTN

and VoIP telephony, while the findings regarding VoIP and mobile telephony are completely mixed. 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. Cecere & Corrocher (2011) use the UK consumer survey data, concluding that IT literacy drives the VoIP diffusion. They find 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. In another more recent study, 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. 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.

### 3 Empirical analysis

#### 3.1 Econometric specification

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

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

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. Country fixed effects are captured by  $\gamma_i$ , while  $\nu_{i,t}$  is an unobserved error term. We rewrite equation (1) as follows:

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

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.  $|\alpha_1| > \alpha_2 > \alpha_3 > 0$ , with  $\alpha_j = \frac{\partial q_f}{\partial p_j}$ , since variables are measured in logarithms.

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, 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) likely 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  $\nu_{it}$ . Fourth,  $HHI^{inter}$  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. 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 and (b) exogeneity, i.e. zero correlation with the error term. We instrument the 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 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 3.3.

## 3.2 Data

We employ the unbalanced panel data set comprising 25 EU countries for the 2006:Q2 - 2011:Q4 period.<sup>6</sup> Our data is of biannual frequency. Subscription and price data are obtained from 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 various sources, such as the 'Progress Reports on Single European Electronic Communications Markets'.

Table 1 provides a descriptive statistics of our data set.<sup>7</sup> Variable  $q^{fix}$  represents the fixed

<sup>6</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>7</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
$income$	-4.514	0.622	-6.149	-3.441	298
$house$	15.277	1.136	13.258	17.519	300
$llu$	11.1	0.333	0.693	16.077	305
$pop_{den}$	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

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 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.  $HHI_{i,t}^{intra}$  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.  $llu$  measures all fully unbundled local-loops in a country,  $ftf$  and  $mtr$  denote fixed-to-fixed and fixed-to-mobile termination rates set by each national

regulatory authority (NRA). 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.

### 3.3 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.

Table 2: Estimation results

Dependent Variable:	$q_{i,t}^{fix}$	
	FE	FEIV
$p_{i,t}^{fix}$	-0.018 (0.02)	-0.223*** (0.080)
$p_{i,t}^{VoIP}$	0.005 (0.008)	0.042** (0.020)
$p_{i,t}^{mob}$	0.025 (0.021)	0.102** (0.041)
$q_{i,t-1}^{fix}$	0.960*** (0.023)	0.971*** (0.037)
$HHI^{inter}_{i,t}$	0.109 (0.073)	0.136 (0.101)
$HHI^{intra}_{i,t}$	0.024 (0.041)	0.154** (0.074)
$income_{i,t}$	0.021 (0.029)	0.013 (0.043)
$house_{i,t}$	0.037 (0.231)	0.680 (0.448)
Intercept	-0.011 (3.850)	- -
N	192	138
R <sup>2</sup>	0.971	0.973
F	676.7	667.0
Hansen's j $\chi^2$		6.910
Underidentification		16.308***
Hausman $\chi^2$		15.87**

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

Heteroskedasticity robust standard errors are reported in parentheses.

P-values are reported in squared brackets.

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 short-run own-price elasticity of PSTN services is -0.223, significant at the 1% level. Short-run cross-price elasticities of mobile and VoIP services are 0.102 and 0.042, respectively, both at 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:  $|\alpha_1| > \alpha_2 > \alpha_3$ . The estimated short-run elasticities are of a similar or even higher magnitude compared to previous studies. The reason behind may be the actuality of our data set. Long-run elasticities can be calculated as  $\eta_j = \frac{\alpha_j}{1-\phi}$ , yielding own-price elasticity of -7.79, and cross-price elasticities of 1.45 and 3.5 for VoIP and mobile services, respectively. Substantial larger long-run elasticities are in line with typical 12-24 month contract-duration. Overall, the results indicate strong substitutability between PSTN and other types of telephony. Demand-substitution is found to be especially prevalent for mobile.

## 4 Conclusion

This study investigated the patterns of substitution between PSTN, VoIP and mobile voice services. Using a unique and very recent data set on 25 EU countries for the 2006:Q2 - 2011:Q4 period and applying dynamic estimation techniques, we obtain the following estimation results.

Consumers perceive VoIP and mobile telephony as substitutes for the traditional fixed-line. Estimated short-run 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. Long-run elasticities are clearly in the elastic range. Demand-substitutability is a prerequisite for market deregulation. The most recent version of the European Commission's Recommendation from October 2014 excludes the markets on access to and call origination on the public telephone network provided at a fixed location from the list, and thus pays attention to the current market developments. Further, installed base and lower degree of intramodal competition have a positive significant effect on the current number of subscribers. In a nutshell, traditional fixed-line telephony is being replaced with mobile and VoIP services. Mobile seems to restrict fixed-line providers even stronger. So far, only very few studies have analyzed PSTN and VoIP interrelation, whilst there is a broader range of literature examine fixed-to-mobile substitution. Surprisingly, there exists no comprehensive study of PSTN, VoIP and mobile, which estimates demand elasticities. This is the main contribution of our paper whereby we fill a wide-open research gap.

The results of our analysis have important policy implications. Our findings are in line with those of some studies, which already suggested that Markets 1/2007 and 2/2007 should be deregulated due to competitive pressure from VoIP and mobile. There is credible evidence

for substitution between PSTN and VoIP, which is already considered one market. Substitution between VoIP and mobile, as found by Cecere & Corrocher (2012), and strong substitution patterns between wireline and wireless technologies hint at a joint market definition, at least in the future. 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. Market 1/2007 has been already deregulated in a handful of countries, e.g. the Finnish regulator (FICORA) has already deregulated PSTN access market on the basis of strong substitution between fixed and mobile services. However, deregulation has to be put into force carefully and potential implications of lifting the deregulation need to be examined under consideration of the national competitive environment. E.g. Germany's NRA (Bundesnetzagentur) has recently announced to stick with some form of ex ante regulation, precisely carrier pre-selection, given that carrier pre-select users are generally found among socially disadvantaged groups.<sup>8</sup> In the case of deregulation, national authorities must ensure reasonable terms of use for captive users, i.e. subscribers who cannot give up on their fixed-line connection.

The change in regulation, however, seems justified by sufficient competitive pressure exerted by VoIP and mobile services at a EU-level. Hence, our results underpin the Europeans Commission's current decision to lift the ex ante regulation on the fixed-line telephony market.

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<sup>8</sup>[http://www.bundesnetzagentur.de/cln\\_1912/SharedDocs/Pressemitteilungen/DE/2014/140320\\_RahmenBedFestnetz.html?nn=265778](http://www.bundesnetzagentur.de/cln_1912/SharedDocs/Pressemitteilungen/DE/2014/140320_RahmenBedFestnetz.html?nn=265778).

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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