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Substitution Between Fixed, Mobile, and Voice over IP Telephony – Evidence from the European Union*

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May 2016

Abstract

Developments in the EU telecommunications markets require a recurrent redesign of the regulatory framework for telecommunications services. In this regard, the analysis of the substitution effects between different types of telephony is the cornerstone of market definition and therefore of effective regulation. This paper explores the access substitution between fixed-lines, mobiles, and managed VoIP in a unified EU cross-country framework. We employ a half-yearly dataset for 20 EU countries for the 2008–2011 period and apply dynamic panel data methods. Our analysis demonstrates strong access substitution between fixed-lines and mobiles and provides indicative evidence on the substitution between fixed-lines and VoIP. Overall, we find evidence in favor of access substitution and therefore of joint market definition. Regulatory obligations imposed on the market for access to fixed telephone networks might therefore be redundant.

JEL classification: C23, L43, L51, L96.

Keywords: Fixed-mobile-VoIP substitution; Telecommunications markets; (De)regulation; Market definition; Dynamic panel data analysis.

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1 Introduction

The national telecommunications sectors have in the past operated as natural monopolies. State-owned carriers were in charge of maintaining and providing access to the national copper-based fixed telephone network.[1] The industry landscape began changing in the 1990s, when mobile telephony became widespread due to the deployment of GSM technology. In the same period, fixed network incumbents began providing Internet services through the existing copper-based infrastructure. In one of the first liberalization attempts, the US Telecommunications Act of 1996 imposed access obligations on incumbent carriers to allow for network interconnection. The EU followed suit in 1998. Nowadays, wholesale access obligations still remain in place in most European countries (European Commission, 2014c). The incumbent carriers are required to lease the copper infrastructure to entrants at regulated (usually cost-based) access prices.

Recent developments in the EU telecommunications markets challenge the viability of the existing regulatory framework (Briglauer et al., 2011; Barth and Heimeshoff, 2014a,b). Fixed-line services have been in decline for several years. In contrast, staunch competition in the mobile sector and the resulting price drop have advanced the spread of mobile telephony (European Commission, 2013, p.63). Broadband coverage is almost universal: at the end of 2013, more than 97% of all EU homes had access to fixed broadband, 62% of which were covered by ultra-fast broadband (European Commission, 2014a). The deployment and uptake of (ultra-)fast broadband provided an impetus for the expansion of VoIP telephony as its quality critically depends on the underlying connection speed.[2] If an emerging communications service such as VoIP becomes a substitute for the existing ones, the competitive boundaries might shift, which has to be considered in the regulatory decision-making.

The European Commission's 'Recommendation on relevant product and service markets

[1] The term fixed telephone network is equivalent to Public Switched Telephone Network (PSTN) and Plain Old Telephone Service (POTS). It refers to the international telephone system based on copper wires carrying voice data in the form of analog waves. Fixed telephony includes markets for access, call origination, and call termination on the public telephone network provided at a fixed location.

[2] VoIP, or broadly Internet telephony, is a methodology and a group of technologies that enables the usage of the Internet as the transmission medium for telephone calls. This type of telephony is digital, i.e., voice signals are translated into binary data instead of analog waves. The data packets are then transmitted via Internet Protocol (IP). VoIP can be unmanaged and managed. Unmanaged VoIP (also pure VoIP service, i.e., a peer-to-peer application) is based on a software developed by independent content providers and is not regulated. Typical examples include Skype and Viber. From the demand side, managed VoIP is nearly equivalent to the traditional fixed telephony. Consumers make and receive calls using a telephone gadget and are assigned a geographic or non-geographic number. Termination rates for calls to and from managed VoIP are regulated.

within the electronic communications sectors' has recently suggested that *ex ante* access obligations from the markets for access (market 1/2007) and call origination (2/2007) on the public telephone network provided at a fixed location can be removed.[3] While the decision to discontinue the regulation was in the past based on meeting the Three test criteria, national regulators are nowadays obliged to provide evidence that a market has failed the test in order to retain the regulation. The burden of proof has thus been reversed.[4] The decision to deregulate is, inter alia, based on the degree of substitution between fixed-lines and other telephone services (European Commission, 2014c; FICORA, 2013). The Commission underlines that, although both mobiles and VoIP constrain the fixed incumbent carriers, only managed VoIP is a proper substitute for fixed-lines. This conclusion is based on the differences in features, contracts, and consumption patterns between mobile and fixed-line telephony.

Surprisingly, the empirical literature is almost silent with regard to VoIP telephony and its relationship to other communications services. Few existing studies on VoIP examine the traffic substitution and deal almost exclusively with unmanaged VoIP, i.e., peer-to-peer applications. However, analyzing managed VoIP, which is regarded as a possible substitute for a fixed-line due to its similarities from the demand side, is critical in the light of changed market conditions and the necessity to redesign the existing regulatory framework. To the best of our knowledge, a coherent analysis of the access substitutability between fixed-line, mobile and managed VoIP telephony has been absent from the literature. Our paper attempts to bridge this research gap. We address the following questions: (a) what is the extent of access substitution between fixed-lines and managed VoIP? (b) and how is the demand for fixed-lines and managed VoIP affected by mobiles? We focus on access instead of traffic substitution because the former is more relevant from the regulatory perspective and there is a lack of any empirical evidence on this issue.

We employ a half-yearly dataset for 20 EU countries spanning the 2008–2011 period and apply dynamic panel data methods. Our main interest is the estimation of own-

[3]This decision is based on the conclusion that both markets fail the Three criteria test. First, the Commission argues that entry barriers are no longer substantial, given that market entry is possible on the basis of leasing the existing or deploying the own infrastructure. Second, VoIP telephony and mobiles constrain the market power of fixed-line incumbents, with the tendency toward more effective competition in the future. Finally, if *ex ante* access obligations are removed, competition law alone is sufficient to address the remaining market failures.

[4]Currently, markets 1/2007 and 2/2007 have been deregulated in only a few countries. *Ex ante* access obligations have been removed from the market 1/2007 in Finland, Lithuania, Romania, and Slovenia and from the market 2/2007 in Finland and Romania only (European Commission, 2014c). The Netherlands and the UK impose limited remedies on the non-competitive segments (single calls and the ISDN2 and ISDN30 access markets, respectively) of the market 1/2007 (ECORYS, 2013, p.78).

and cross-price elasticities between fixed-lines, mobiles, and managed VoIP, which are indicative of the possibility of market power abuse.[5] Our results indicate a strong access substitution between fixed-lines and mobiles and provide vague evidence of their substitution with managed VoIP at the EU level. Second, bundling strategies are essential for maintaining the subscription base in the market for fixed-lines. Contrary to the Commission's appraisal, our findings suggest that fixed-lines and mobiles likely constitute part of the same market. Overall, we find evidence in favor of access substitution and, therefore, of joint market definition. *Ex ante* access obligations imposed on copper-based incumbents might therefore be redundant. However, in the short-run, national regulators might need to consider targeted remedies in order to protect the captive group. In this case, the regulatory framework must be redesigned in a way that is conducive to competition and innovation.

The paper is organized as follows. In Section 2, we summarize the relevant literature. Section 3 outlines the empirical strategy and describes our dataset. The results are presented in Section 4, before the discussion on policy implications in Section 5. Finally, Section 6 concludes.

2 Literature review

A large body of the literature explores traffic and access substitution between fixed-lines and mobiles on both single- and cross-country levels. Studies on VoIP, on the other hand, are scarce and focus only on traffic-level substitution and unmanaged VoIP systems. A detailed literature overview is provided in Tables A1 and A2 in the Appendix.

The first strand of literature analyzes the substitution between fixed-lines and mobiles on a country level. In one of the pioneering works, Rodini et al. (2003) employ a binary logit model with a US household survey panel data for 2000–2001, documenting access substitution between mobiles and the second fixed-line. Making use of an extended US households survey conducted over the 1999–2001 period, Ward and Woroch (2004) provide evidence of traffic-level substitution. In a related study, Ward and Woroch (2010) employ the same dataset and use a US price subsidy for fixed telephony as

[5] Market power abuse by the incumbent carriers in the case of deregulation could lead to unfavorable conditions for consumers (European Commission, 2014b, p.21, BEREC, 2014, pp.15-17, Vodafone, 2014, pp.4-7). This pertains primarily to the captive users, who cannot disconnect from the fixed-lines due to the lack of alternatives. The reasons for the captivity are twofold. First, fixed-lines provide access to services which are not compatible with either VoIP or mobiles, including fax, alarm systems, remote maintenance and monitoring applications. Second, for technical reasons, legacy copper-based equipment cannot always be operated by IP solutions, which creates high switching costs (BEREC, 2014, p.16).

a natural experiment in their difference-in-differences analysis. Their results indicate modest access substitution between fixed-lines and mobiles. More recently, Ward and Zheng (2012) provided evidence of access substitution in China, using data for 1998–2007 and applying an Arellano-Bond-type linear dynamic panel model. Employing a logistic model with household survey data for 2004–2009, Suárez and García-Mariñoso (2013) deduce that access substitution between fixed-lines and mobiles in Spain is driven by the type of broadband access, network effects, age, household size and, to a lesser extent, price. Karacuka et al. (2011) analyze the demand for mobile telecommunications services in Turkey. Using operator-level panel data from 2002 to 2006, the authors document strong evidence of traffic-level substitution. The substitution effect is stronger for pre-paid than for post-paid consumers. Briglauer et al. (2011) utilize a sample of Austrian market-level data from 2002 to 2007 to conclude that the demand for fixed-line access is inelastic, while the demand for fixed-line calls is elastic.

The second group of studies employs aggregated cross-country data to explore the relationship between fixed-lines and mobiles. Garbacz and Thompson (2007) estimate a fixed-effects model using a sample of 53 less-developed countries (LDC) from 1996 to 2003. They find that fixed-lines are substitutes in the mobile market, while mobiles may be considered complements in the fixed-line market. Barth and Heimeshoff (2014a,b) employ a dynamic panel data approach in a sample of EU countries, documenting both access and traffic substitution. Other recent studies focus on the role of broadband technologies in fixed-mobile substitution. Using a dataset for 27 EU countries for the 2005–2010 and 2005–2011 period, respectively, Grzybowski (2014) and Grzybowski and Verboven (2016) estimate a discrete choice model of household demand for 'fixed-line only', 'mobile only', and both 'fixed-line and mobile access'. Both studies provide evidence of fixed-mobile substitution. Furthermore, higher fixed broadband penetration is shown to increase the complementarity, while the spread of mobile broadband increases the substitutability between fixed-lines and mobiles. Grzybowski and Verboven (2016) also provide evidence of an incumbency advantage: a dominant position in the fixed-line market can be leveraged into the mobile market.

The second strand of literature analyzes VoIP and its relationship with other telephony services. Most studies analyze individual countries and provide scant econometric evidence on intermodal traffic substitution. Cecere and Corrocher (2011) investigate the usage patterns of mainly unmanaged VoIP services, such as Skype and MSN messenger, by estimating a probit model in a sample of UK consumer survey data from 2006.[6] The

[6]In their dataset, Skype is by far the most popular application with 67% of the respondents using

authors find that VoIP calls are made more regularly if a household has not subscribed to fixed-line, while the VoIP usage intensity is unaffected by the levels of mobile subscription. In contrast, Cecere and Corrocher (2012) use a sample of Italian consumers from 2006 and conclude that mobile telephones negatively affect the usage of unmanaged VoIP. The usage of other IP services (e.g., chat and mail applications), which is associated with deepened IT skills and higher perceived ease of use, slightly increases the probability of using VoIP applications. Unlike the two aforementioned studies, Kwak and Lee (2011) use time-series data from 2006–2009 and employ an instrumental variable approach to analyze the traffic substitution between managed VoIP and other communications services in South Korea.[7] The authors conclude that the usage intensity of managed VoIP is driven by VoIP call rates, fixed-line call rates, and network effects, but is not affected by the pricing of mobile services.

Overall, the literature provides convincing evidence of fixed-mobile substitution on both an access and traffic level, while the evidence on traffic substitution between VoIP and other communications services is inconclusive. The latter is partly due to the relatively old datasets and short time-series. Against this backdrop, our study is the first to investigate the access substitution between VoIP and other communications technologies. We employ a recent dataset and set up a coherent framework for the analysis of the substitution between fixed-lines, mobiles, and managed VoIP.

3 Model specification and data

3.1 Empirical strategy

A number of studies demonstrate that the subscription and usage patterns of telephony services are characterized by path dependence (Karacuka et al., 2011; Ward and Zheng, 2012; Barth and Heimeshoff, 2014a,b). The reasons for this are twofold. On the one hand, habits and routines thwart prompt adaptation of consumer behavior in the face of changed market conditions. On the other hand, most service contracts are not irrevocable at any time, which precludes their cancellation before the actual expiration date. Following Houthakker and Taylor (1970), we capture the demand persistence using the lagged values of the subscription levels. We further assume that the subscrip-

it, followed by MSN (18%), BT/Yahoo! (16%), Tesco (6%), plus Orange (Wanadoo) and Google (both 4%).

[7] Note that the validity of the instruments included in this study is debatable if the contract length exceeds one month.

tion volumes are driven by both current and lagged prices, since the cancellation and subscription decisions might not be immediate. We specify the demand function for technology $K = \{fix,\ mob,\ voip\}$ in period t as:

$$k_{sub_t} = f(k_{sub_{t-1}}, p_{k_t}, p_{k_{t-1}}, \mathbf{p}_{k_t}, \mathbf{p}_{k_{t-1}}, X_t),$$

where $k \in K$ denotes fixed, mobile or managed VoIP telephony, k_{sub} is the demand for k measured in terms of the subscription base, p_k is the price of service k, $\mathbf{p}_k = (p_l \mid \forall l \in K_{-k})$ is the price vector of all potential substitutes of k, and X_t is a vector of demand shifters which includes the number of broadband connections, the number of fixed incumbents' subscribers in the mobile market, and the monthly income per capita. Making use of the panel structure of our dataset, we define the demand for service k in country i at time t as:

$$\begin{aligned} k_{sub_{it}} = \alpha + \beta_k k_{sub_{it-1}} + \sum_k \gamma_k p_{k_{it}} + \sum_k \delta_k p_{k_{it-1}} \\ + \sum_k \theta_k X_{k_{it}} + \eta_i + \nu_{it}, \end{aligned}$$

where η_i represents the time-constant country fixed-effect and ν_{it} is an unobservable error term.

Considering that all contracts begin at different points in time and that contractual durations vary, we include the first lag of the dependent variable to capture the average demand persistence. Including a maximum of one lag is a compromise due to the degrees of freedom considerations. According to the economic theory of a downward sloping demand curve, the effect of own price on demand is predicted to be negative. Concerning the prices of other services, a positive coefficient indicates substitutability, while a negative one is indicative of a complementary relationship. The impact of fixed broadband is expected to differ across technologies. First, Grzybowski and Verboven (2016) show that more broadband connections lead to complementarities between fixed and mobile telephony, due to incumbent carriers' ability to leverage their dominant position in the fixed-line network into the mobile market. Second, high-speed broadband ensures a higher quality voice service, thereby providing an impetus for VoIP adoption. Additional bundling strategies and the strategic behavior of fixed-line incumbents are controlled for by accounting for their subscription base in the mobile market.[8] Carriers

[8] As a robustness check, we separately control for an incumbent's number of DSL connections, con-

active in two or more markets are likely to behave strategically by maximizing their joint profit instead of pursuing profit-maximizing behavior in each market separately. This can affect contract features and, ultimately, the individual demand for services. Finally, higher incomes are likely to boost the demand for fixed, mobile, and VoIP telephony.

Given our dynamic setup, we apply the Arellano-Bond Generalized Method of Moments (GMM) estimator (Arellano and Bond, 1991) to address the unobserved heterogeneity and endogeneity issues. Due to the large cross-sectional but small time dimension of our dataset, we choose not to estimate a fixed-effects model, as the demeaning transformation would produce inconsistent estimates (Nickell, 1981). The first-difference transformation of the difference GMM estimator, on the other hand, eliminates the time-constant country fixed-effects and therefore captures one source of endogeneity without leading to inconsistencies. We apply the difference GMM instead of the more efficient system GMM estimator, as the latter is consistent only under the assumption of zero correlation between explanatory variables and individual time-invariant effects (cf. Arellano and Bover, 1995; Blundell and Bond, 1998). Individual time-invariant effects capture a range of unobserved factors, including country-specific consumer preferences, geographic characteristics, and initial infrastructure stock. Each of these variables are correlated with prices and/or subscription levels. For instance, carriers are less able to exploit the economies of scale in countries with mountainous terrain, which probably affects the pricing of the telecommunications services. Furthermore, fixed infrastructure stocks in the 1990s differed substantially across EU countries, which determined future investment and consumption patterns (Grzybowski and Verboven, 2016; Grzybowski, 2014). The correlation between explanatory variables and individual time-invariant effects is therefore likely different from zero, implying that the system GMM would be inconsistent.

We estimate the demand using single equation techniques instead of simultaneous multiple equation estimators. The main advantage of system over equation-by-equation estimators is in their efficiency. However, the system estimators are consistent only if all equations are specified correctly. The improved efficiency thus comes at a high cost, since the misspecification in one equation spills over to the estimates of all other equations. Considering we explore a fairly complex market with substantial differences in the underlying technologies, we choose a single equation estimator which is expected to produce consistent demand estimates.

In our specification, the lagged dependent variable is correlated with the error term and is thus clearly endogenous. Due to unobserved demand shocks, own prices and prices

sidering that fixed-line telephony is often bundled with copper-based broadband DSL.

of substitutes are potentially endogenous, too (cf. Caves, 2011). In order to address the endogeneity, we apply an instrumental variable approach. We employ two sets of instruments: (i) lagged levels for lagged dependent and price variables (Arellano and Bond, 1991) and (ii) cost shifters for price variables. The latter group of instruments are valid because costs have no direct impact on subscription decisions, but influence the endogenous price variables. We use the termination rates as cost shifters, as they are directly incorporated into the calling prices and are the only observable cost shifters (cf. Barth and Heimeshoff, 2014a). Moreover, termination rates are set by the national regulators and are kept constant until the European Commission approves changes after a new round of regulation. Hence, they can be considered exogenous. In line with Briglauer et al. (2011), we include both fixed-to-fixed and fixed-to-mobile termination rates. Since the regulatory changes are likely to affect prices with some delay, we employ their lagged, instead of current, values.

In order to avoid spurious correlations, we test for the presence of a stochastic trend in each variable. The results of the panel unit root test are presented in Table A3. Fixed-line and mobile subscriptions are stationary in levels and in differences, whereas VoIP subscription is stationary in differences only. Since the Arellano-Bond GMM estimator is based on differences, our specification does not suffer from spurious correlation problem. Cointegration, i.e., long-term relationship between the variables, cannot be present either, given that the dependent and explanatory variables are integrated of different orders (Hamilton, 1994).

3.2 Data

Our dataset comprises 20 EU countries from the second quarter 2008 through the fourth quarter 2011 at six-month intervals.[9] Our main data sources are: Analysys Mason and Eurostat. Data on the subscription levels, prices, number of broadband, DSL, cable, other fixed broadband lines and also mobile broadband connections are retrieved from Analysys Mason. GDP per capita and the consumer price index (CPI) are provided by Eurostat, while population density is taken from the World Bank. Information on fixed-to-fixed and fixed-to-mobile termination rates are from the 'Progress Reports on the Single European Electronic Communication Market' and are supplemented by data from the OECD and the national regulatory authorities where necessary. Table A5 provides a detailed description of our dataset.

[9] All countries included in this study are listed in Table A4 in the Appendix.

The regression variables are defined as follows. Fixed-line demand represents the number of active analogue circuit-switched retail subscribers, measured as the number of active channels. Mobile demand is defined as the number of active individual mobile connections, including both pre-paid and post-paid users. Managed VoIP demand refers to the number of active channels of either paid-for native VoIP services that use a broadband access connection or VoIP services included in a paid-for bundle with broadband access. Thus, peer-to-peer applications are excluded. The fixed-line price is expressed as the sum of the access fee and calling price, both calculated as the average revenues per line. As is common in other studies, we proxy for the price of mobile telephony by the average revenue per user (cf., e.g., Ward and Zheng, 2012). The price of VoIP is calculated as the unweighted average price of all double-play contracts, which include both a broadband and a managed VoIP connection. The measure of the average VoIP price might therefore slightly overestimate the actual VoIP price.

In our regression equations, each variable is expressed in logarithms in order to be interpreted as elasticity. The price-related variables are measured in euros and deflated using the CPI with the year 2005 as the base period. Summary statistics are presented in Table 1 and the correlation matrix between the variables in Table A6.

Table 1: Summary statistics

Variable	**Measured in**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
fix_{sub}	Channels	6939906	8382992	315000	29097000	160
mob_{sub}	Active subscribers	27849168	29826034	1658000	106370000	160
$voip_{sub}$	Channels	2055037	4064357	11000	20618000	160
p_{fix}	Euro	35.20	10.43	12.80	70.44	160
p_{mob}	Euro	23.94	7.99	9.41	47.54	160
p_{voip}	Euro	38.11	11.01	10.34	74.63	160
bb_{lines}	Channels	5921575	7248068.868	299000	26902000	160
inc_{mob}	Active subscribers	6524140	11211720	744000	36942060	160
gdp_{pc}	Euro	6489.83	3139.26	1459.79	12618.30	160
inc_{dsl}	Channels	3086100	3979930.308	130000	14191000	160
$cable/other_{bb}$	Channels	1103025	857534.809	113000	3864000	160
$mobile_{bb}$	Active Subscribers	1242321	8884263	12057	39115680	160
pop_{dens}	Inhabitants per km^2	143.422	113.901	22.516	496.389	160
ftr	Euro cents	0.65	0.31	0.01	1.58	160
mtr	Euro cents	6.42	2.75	2	18.82	160

Note: All variables are expressed in levels.

4 Empirical results

4.1 Main results

The Arellano-Bond GMM estimator is sensitive to the lag structure (e.g., Arellano and Bover, 1995; Blundell and Bond, 1998). Therefore, we estimate two models with different sets of instruments. In Model A, we include the fourth lags of the subscription levels and prices. As our dataset is of half-yearly frequency and some contracts have a 24-months duration, this specification should not suffer from the endogeneity problem. Considering that most contracts are shorter than 24 months, Model B employs the second and the third lag of the dependent variable and the second lag of price variables as instruments.[10] Estimation results from our baseline specification are presented in Table 2.

Due to the first-difference transformation of the GMM estimator, the residuals have a moving average structure and are possibly first-order autocorrelated. Autocorrelation AR(s) of a higher-order would imply that the s-th lag of the dependent variable is endogenous, and consequently not a valid instrument. For Model A, the Arellano-Bond test indicates no presence of fourth-order autocorrelation. Hence, the instruments can be considered valid. For Model B, the test rejects the presence of autocorrelation of a higher-order except for the mobile market, implying second-order autocorrelation.[11] We further test for the exogeneity of the instruments by applying the Sargan-Hansen's J test. With p-values ranging from 0.33 to 0.68, the test statistics indicate that the null hypothesis of valid over-identifying restrictions cannot be rejected in either regression.

The results of the fixed-line demand estimation are presented in column (1) for Model A and in column (4) for Model B. The lagged subscription volume has a highly positive impact on contemporaneous demand, implying that a large share of current subscribers do not cancel their contracts in the next period. The demand for fixed-lines is therefore path-dependent. The current own-price elasticity is negative and is within the inelastic range (-0.308 and -0.316). The lagged own-price elasticity is insignificant in Model A but significant in Model B, indicating some long-run price effect on the demand for fixed-line access. The current and the lagged mobile prices are positive and significant,

[10] Our pricing data shows that, on average, 82% of all double-play offers with fixed-lines and broadband have a contract length up to 18 months and 72% up to 12 months. Concerning the double-play offers consisting of VoIP and broadband, 79% of contracts are up to 18 months long, while 72% are up to 12 months long. Concerning the mobile market, around 50% of subscribers use the prepaid services with no contractual obligations.

[11] Given that we apply an equation-by-equation estimation, the fixed-line and VoIP estimation are unaffected by this potential inconsistency in the mobile telephony equation. Note further that the estimation results also hold if only the third lag is included. Hence, the bias is probably small.

Table 2: Estimation Results

	Model A			Model B		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	$fix_{sub_{it}}$	$mob_{sub_{it}}$	$voip_{sub_{it}}$	$fix_{sub_{it}}$	$mob_{sub_{it}}$	$voip_{sub_{it}}$
$fix_{sub_{it-1}}$	0.777***			0.813***		
	(0.109)			(0.068)		
$mob_{sub_{it-1}}$		0.436**			0.516***	
		(0.195)			(0.161)	
$voip_{sub_{it-1}}$			0.940***			0.658***
			(0.071)			(0.084)
$p_{fix_{it}}$	-0.308*	0.151*	-0.197	-0.316***	0.140**	0.247
	(0.157)	(0.082)	(0.592)	(0.119)	(0.072)	(0.440)
$p_{fix_{it-1}}$	-0.246	0.146	-0.412	-0.220*	0.107	0.998**
	(0.172)	(0.113)	(0.404)	(0.127)	(0.104)	(0.497)
$p_{mob_{it}}$	0.268***	-0.220*	0.510	0.234***	-0.264**	-0.136
	(0.100)	(0.126)	(0.407)	(0.067)	(0.109)	(0.334)
$p_{mob_{it-1}}$	0.178*	-0.020	0.327	0.138*	0.074	-0.616
	(0.104)	(0.082)	(0.326)	(0.079)	(0.059)	(0.402)
$p_{voip_{it}}$	-0.018	-0.039*	-0.185***	-0.012	-0.033*	-0.241**
	(0.031)	(0.022)	(0.064)	(0.019)	(0.017)	(0.109)
$p_{voip_{it-1}}$	-0.031	0.008	0.081	-0.024	0.015	-0.039
	(0.019)	(0.020)	(0.116)	(0.019)	(0.023)	(0.087)
$bb_{lines_{it}}$	0.031	-0.020	0.222	0.016	-0.030	0.635**
	(0.111)	(0.088)	(0.245)	(0.107)	(0.078)	(0.305)
$inc_{mob_{it}}$	0.237**	0.067	0.650**	0.204**	0.069	-0.009
	(0.104)	(0.116)	(0.303)	(0.103)	(0.112)	(0.217)
$gdp_{pc_{it}}$	-0.014	0.140***	-0.240*	0.004	0.156***	-0.222
	(0.049)	(0.040)	(0.144)	(0.033)	(0.033)	(0.198)
N	120	120	120	120	120	120
Sargan Test χ^2-stat	16.15	17.42	13.80	25.21	22.63	27.59
p-value	0.51	0.43	0.68	0.45	0.60	0.33
AR(2), Prob> z				0.77	0.01	0.42
AR(3), Prob> z				0.13	0.32	0.59
AR(4), Prob> z	0.28	0.15	0.79			

Significance levels *: 10% **: 5% ***: 1%. Heteroscedasticity robust standard errors in parentheses.
We instrument the lagged dependent and all price variables with their corresponding lags and cost shifters.
Sargan test: H0: Overidentifying restrictions are valid. AR test: H0: No autocorrelation.

implying substitution from fixed-lines to mobiles. This result is in line with the existing literature and with the overall trends in telecommunications markets, which indicate an increasing importance of mobiles at the expense of fixed telephony. Surprisingly, the impact of VoIP prices on the demand for fixed-lines is insignificant at the aggregate EU level. Managed VoIP might nonetheless restrict the fixed-line carriers with the threat of potential market entry. This threat is credible due to an increasing availability of (ultra-)fast broadband, which fosters the transition from copper- to IP-based networks. We find a positive and significant effect of the number of fixed incumbents' subscribers in the mobile market. The ability to offer bundles constitutes an important factor in maintaining the subscription base and, ultimately, in slowing down the decay of fixed telephony. The number of broadband lines and monthly income per capita are insignificant. The former might be due to the declining market shares of copper incumbents in the broadband market, while the latter indicates that the demand for fixed-lines is primarily determined by the development of a fixed-network infrastructure.

The results of mobile demand estimation are presented in columns (2) and (5). The lagged subscription volume has a positive and significant effect on the contemporaneous demand (+0.436 vs. +0.516). The current own-price elasticity is negative (-0.220 and -0.264), while the lagged own-price elasticity is insignificant. The current cross-price elasticities of mobiles with respect to fixed-lines are positive and significant in both models, providing evidence of fixed-mobile access substitution. A price increase of fixed-lines by 1% increases the demand for mobile telephony by 0.14–0.15%, implying that consumers respond to higher fixed-line prices by shifting away to mobiles. Mobile telephony therefore constrains the market power of fixed-line carriers. The current cross-price elasticity of mobiles with respect to VoIP is negative and significant (-0.039, -0.033), which is indicative of the complementarity between the technologies. The spread and higher affordability of VoIP might have increased the range of the communications options and slightly boosted the adoption of mobiles. However, given a high penetration and the affordability of mobiles in the EU, small price changes in VoIP services are unlikely to alter the mobile demand significantly. The variable number of broadband lines and the number of fixed incumbents' subscribers in the mobile market are insignificant, while the income per capita has a positive and significant effect on mobile demand.

Analogously to fixed-lines and mobiles, managed VoIP demand exhibits strong path dependence (columns 3 and 6). The own-price elasticity is negative (-0.185 and -0.241), while the lagged own-price elasticity is insignificant. The lagged cross-price elasticity of VoIP with respect to fixed-line telephony is positive and significant in Model B. Given the

strong advocacy of the European Commission for the joint market definition for VoIP and fixed-lines, substitutability between the two services should be expected. However, the evidence is not very robust. The cross-price elasticities of VoIP with respect to mobiles are insignificant, indicating a one-way complementary relationship. We find a positive effect of the number of fixed-broadband lines on the demand for VoIP access. This effect may be due to VoIP being provided as a cheap add-on to broadband connections and the fact that (ultra-)fast broadband increases voice quality and thereby the attractiveness of IP-based communication services. Moreover, we document a positive impact of the incumbent's subscription base in the mobile market on VoIP access demand. Overall, the analysis provides evidence of incumbents' ability to leverage their dominant position in one market to another by offering bundles of fixed-mobile or VoIP-mobile telephony. This underlines the importance of bundling strategies in the telecommunications industry.

4.2 Robustness checks

We assess the robustness of our results by employing two additional specifications.[12] The lag structure in both robustness checks is equivalent to Model A, since the corresponding specification in Model B might induce a bias in mobile demand equation. The first specification (Model C) is in the spirit of Grzybowski (2014) and Grzybowski and Verboven (2016). We decompose the variable number of broadband lines into cable and other fixed broadband (including fibre) and mobile broadband. Additionally, we account for the effect of bundling the copper-based DSL broadband with fixed-lines by including the number of incumbents' active DSL lines. In the second specification (Model D), we interact the VoIP price with the number of broadband lines. Higher broadband penetration expands the potential VoIP market, thereby raising the demand for VoIP access. Given that the coverage and quality of fixed-line networks in developed and more densely populated countries tend to be more advanced, while the usage of telecommunications services is likely more intensive, both specifications include GDP per capita and population density (cf., e.g., Caves, 2011; Barth and Heimeshoff, 2014a). The results of the robustness checks are presented in Table A7.

Both specifications confirm our main results. We document path dependencies in the subscription patterns for each telephony service and a strong substitution from fixed-lines to mobiles. Again, fixed-mobile substitution is weakened by bundling strategies: the presence of fixed-line carriers in the mobile market and/or increased number of

[12] As a further robustness check, we included a linear and a quadratic trend. Since both variables are insignificant and the results remain unchanged, we do not report the results.

incumbents' DSL subscribers in the broadband market help maintain the fixed-line subscription base. The results also confirm the complementarity between mobile and VoIP telephony, as well as the positive relationship between income and the adoption of mobiles. The current own-price elasticity of VoIP demand is significant. However, the same does not hold for cross-price elasticities.

5 Policy implications and discussion

The key advantage of our estimation approach is the possibility to disentangle short- and long-run elasticities.[13] Table 3 presents own- and cross-price elasticities for fixed, mobile, and VoIP telephony. The estimated short-run elasticities are comparable in magnitude to those from other single- and cross-country studies. However, the long-run elasticities exceed previous estimates (Barth and Heimeshoff, 2014a; Karacuka et al., 2011; Briglauer et al., 2011). This is likely due to the structure of our dataset, which spans a relatively recent period and enables us to capture "the latest and arguably most dramatic developments" in the telecommunications sector (Vogelsang, 2010, p.14).

Table 3: Short- and long-run own-price elasticities

		Model A			Model B		
		fix_{sub}	mob_{sub}	$voip_{sub}$	fix_{sub}	mob_{sub}	$voip_{sub}$
Short-run:	fix_{sub}	-0.308	0.268	-	-0.316	0.234	-
	mob_{sub}	0.151	-0.220	-0.039	0.140	-0.264	-0.033
	$voip_{sub}$	-	-	-0.185	-	-	-0.241
Long-run:	fix_{sub}	-1.381	2.000	-	-2.866	1.989	-
	mob_{sub}	0.268	-0.390	-0.069	0.289	-0.545	-0.068
	$voip_{sub}$	-	-	-3.083	2.918	-	-0.705

Large long-run demand elasticities raise the question of market definition for voice services. A well-established market delineation approach is the SSNIP test, which compares the estimated long-run own-price elasticities with the critical elasticity ϵ_c. The SSNIP test identifies the smallest relevant market within which a hypothetical monopolist could profitably raise its price while retaining the current subscription base. If the estimated own-price elasticity exceeds ϵ_c, a price increase would lead to lower profits, indicating that the next best substitute has to be included in the market. In line with Vogelsang (2010) and Briglauer et al. (2011), we define the critical elasticity as $\epsilon_c = 1/[m + t]$, where $m = [p - c]/c$ is the price-cost margin and t denotes a "small but significant non-transitory increase in prices", usually 5–10% during a period of 1–2 years. Assuming that

[13] In the Houthakker-Taylor model, the short-run elasticities are directly estimated as γ_k and the long-run elasticities are determined by $(\gamma_k + \delta_k)/(1 - \beta_k)$.

the price-cost margin for fixed-line access is $m = 0.5$ (Stumpf, 2007) and that t takes the value of either 0.05 or 0.1, the critical elasticity falls within the range $\epsilon_c = [-1.82, -1.67]$. The estimated fixed-line elasticity from Model A of -1.38 is below this threshold, while the one estimated from Model B is -2.87 and clearly exceeds ϵ_c. Estimates from the robustness checks are the closest to those from Model B, implying that the own-price elasticities are around 2 in absolute value. Fixed-line telephony can therefore be considered to be part of the same market as mobile and managed VoIP access services at the EU level. Cross-country estimates suggest that the competitive pressure from other services appears sufficient to restrain the incumbent carriers, supporting the European Commission's decision to remove the *ex ante* access obligations from the markets 1/2007 and 2/2007.

Overall, our results provide evidence of the substitution from fixed-lines to mobiles and vice versa and are in line with the existing literature. Mobile operators exert competitive pressure on fixed-line carriers, which diminishes the possibility of market power abuse. The magnitude of the long-run cross-price elasticities between fixed-lines and managed VoIP (+2.918) hints at access substitution toward VoIP, but this effect is not robust. However, considering that our dataset does not cover the post–2011 period and that the access is generally less elastic than the usage, our result is in line with the existing literature on VoIP. Vague evidence of access substitution might be due to the fact that a bulk of subscribers do not switch because of price differences, but are automatically transferred from fixed to VoIP services with the provider's transition to an all IP-based network (ECORYS, 2013, p.195). The threat of potential market entry is nonetheless likely to constrain the price-setting behavior of fixed incumbent carriers. In contrast, the ability to offer service bundles underlines a possible source of market power: if consumers perceive bundles as being superior to single services, carriers providing access to the latter may be in a disadvantageous position. National regulators could therefore consider targeted access obligations to ensure a level playing field for all operators in the market. However, considering the differences in competitive conditions across the member states, this issue must be addressed by each national regulatory authority separately.

Another relevant issue for future regulation is the role of unmanaged VoIP. Most national regulators do not consider this service to be a substitute for managed VoIP, which is due to differences in features and consumption patterns. However, an increased usage of unmanaged VoIP might diminish the relevance of other communications services. Future market definition will consequently depend on a range of factors, including (ultra-)fast broadband penetration, quality of service, pricing, and the possibility of receiving calls

according to domestic or international numbering plans (European Commission, 2014b). On the other hand, providers might block or degrade the over-the-top (OTT) applications which have the potential to erode their revenues. A blockage, however, is likely to be limited in scope, due to the large countervailing power of major OTT applications such as Skype, Facebook, and Viber. Therefore, instead of pursuing a full-scale regulation, it might be possible to deal with this issue under competition law (ECORYS, 2013, p.153).

6 Conclusion

In this paper, we estimate the degree of access substitution between fixed, mobile, and managed VoIP telephony. Our study is the first to investigate the interdependencies between all three types of voice services in a coherent cross-country framework. We use a sample of 20 EU countries in 2008–2011 and apply dynamic panel data techniques to estimate the own- and the cross-price elasticities. Due to the endogeneity of the lagged subscription base and price variables, we apply an instrumental variable approach.

We document strong access substitution between fixed-lines and mobiles and find weak support for the long-run substitution from fixed-lines to managed VoIP telephony. Hence, both telephone services likely constrain the market power of fixed incumbent carriers. On the other hand, bundling raises the demand for fixed-lines. While the substitutability indicates that *ex ante* access obligations imposed on fixed incumbents might be redundant, bundling strategies as a source of market power hint at their necessity. At the EU level, we find evidence in favor of joint market definition and, therefore, of discontinuing the regulation. However, due to different competitive environments across the member states, this issue must be addressed by the individual national regulators. Thus, the question of whether the threat of market power abuse by the fixed incumbents still exists is not answered conclusively. Targeted access obligations might be one of the solutions to protect the captive group of consumers and ensure a level playing field for all operators active in the market. In this case, national regulators must redesign the regulatory frameworks in a way that does not stifle competition and innovation.

In its explanatory note on the deregulation of markets for access and call origination on the public fixed network, the European Commission underlines that (managed) VoIP, and not mobile, is a proper substitute for fixed-lines. Our results, in contrast, suggest a stronger substitutability between fixed-lines and mobiles than between fixed-lines and VoIP telephony. Given its forward-looking perspective, the Commission anticipates that fixed-lines and VoIP will become effective substitutes within the validity period of the

Recommendation. Considering the existence of various "white" and "grey spots" in the EU countries with limited ultra-fast broadband coverage, and the fact that its adoption is path-dependent and therefore somewhat sluggish, this assessment might be too optimistic. Therefore, further research on the substitutability between telephony services with more recent data is necessary to evaluate the effects of regulatory changes. As several fixed incumbent carriers have announced a full-IP transition in upcoming years, this matter might be resolved in the near future.

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Appendix

Table A1: Fixed-mobile substitution studies

Author	Country & Period	Method	Main results
Rodini et al. (2003)	US, 2000–2001	Logit	Moderate access substitution between the second fixed-line and mobile, cross-price elasticity 0.13-0.18.
Ward and Woroch (2004)	US, 1999–2001	LA/AIDS	Moderate fixed-mobile traffic substitution, cross-price elasticity 0.22-0.33.
Ward and Woroch (2010)	US, 1999–2001	Probit/diff-in-diff	Access substitution between the first fixed-line and mobile, cross-price elasticity 0.25-0.31.
Ward and Zheng (2012)	China, 1998–2007	Dynamic panel	Strong fixed-mobile access substitution (FMAS).
Karacuka et al. (2011)	Turkey, 2002–2006	Dynamic panel	Fixed-to-mobile traffic substitution.
Suárez and García-Mariñoso (2013)	Spain, 2004–2009	Logit	Low FMAS. Substitution driven by the broadband connection and socio-demographic characteristics.
Briglauer et al. (2011)	Austria, 2002–2007	Error correction model	Fixed-to-mobile traffic substitution, long-run cross-price elasticity 0.45.
Garbacz and Thompson (2007)	53 LDC, 1996–2003	Fixed-effects	Fixed-lines are substitutes in the mobile market, but mobiles are complements to fixed-lines.
Barth and Heimeshoff (2014a)	EU–27, 2003–2009	Dynamic panel	FMAS, cross-price elasticity 0.18.
Barth and Heimeshoff (2014b)	EU-16, 2004–2010	Dynamic panel	Fixed-to-mobile traffic substitution, cross-price elasticity 0.12.
Grzybowski (2014)	EU, 2005–2010	Discrete choice	FMAS reduced by higher broadband penetration and boosted by the spread of cable and 3G broadband.
Grzybowski and Verboven (2016)	EU, 2005–2011	Discrete choice	FMAS; incumbency advantage in the mobile market; broadband Internet (mainly DSL) reduces substitutability.

Table A2: VoIP studies

Author	Country & Period	Method	Main results
Cecere and Corrocher (2011)	UK, 2006	Probit	Traffic substitution between (mainly) unmanaged VoIP and fixed-line. No relationship between mobile and VoIP usage.
Cecere and Corrocher (2012)	Italy, 2006	Probit	Traffic substitution between mobile and unmanaged VoIP. Use of other IP services increases VoIP usage.
Kwak and Lee (2011)	South Korea, 2006–2009	Static panel	Traffic substitution between fixed-lines and managed VoIP, cross-price elasticity 10.07. Mobile-VoIP traffic substitution insignificant.

Table A3: Maddala-Wu unit root tests

	Levels		**Differences**	
	χ^2	$\chi^2 > p$	χ^2	$\chi^2 > p$
fix_{sub}	58.889	0.027	58.398	0.030
mob_{sub}	53.976	0.069	62.191	0.014
$voip_{sub}$	45.219	0.263	66.987	0.005
p_{fix}	87.787	0.000	88.058	0.000
p_{mob}	82.628	0.000	62.259	0.014
p_{voip}	120.055	0.000	74.645	0.001
bb_{lines}	269.162	0.000	31.668	0.824
inc_{mob}	93.855	0.000	53.346	0.077
gdp_{pc}	22.544	0.988	64.218	0.009
inc_{dsl}	267.227	0.000	98.737	0.000
$cable/other_{bb}$	36.206	0.642	64.756	0.008
$mobile_{bb}$	26.654	0.948	35.874	0.657
pop_{dens}	44.469	0.2891	68.105	0.004
mtr	106.982	0.000	179.420	0.000
ftr	117.979	0.000	114.546	0.000

H0: unit root.

Table A4: Countries

Austria	Ireland	Sweden	Latvia
Belgium	Italy	UK	Poland
Denmark	Netherlands	Bulgaria	Romania
France	Portugal	Estonia	Slovakia
Germany	Spain	Hungary	Slovenia

Table A5: Variables description and source

Variable	Description	Source
fix_{sub}	Number of active circuit-switched retail subscribers.	Analysys Mason*
mob_{sub}	Number of mobile (pre-paid and post-paid) subscribers.	Analysys Mason
$voip_{sub}$	Number of active users of either paid-for native VoIP subscribers or VoIP services included in a paid-for bundle with broadband access; excluding peer-to-peer applications.	Analysys Mason
p_{fix}	Average revenue (subscription + traffic) per fixed-line in euro PPP.	Analysys Mason
p_{mob}	Average revenue per mobile subscriber in euro PPP.	Analysys Mason
p_{voip}	Average price of broadband contracts bundled with VoIP in euro PPP.	Analysys Mason ('Triple-play pricing study')
bb_{lines}	Number of active broadband lines.	Analysys Mason
inc_{mob}	Fixed-line incumbent's share in mobile market (in terms of subscribers).	Analysys Mason
gdp_{pc}	Monthly real GDP per capita in euro PPP.	Eurostat
inc_{dsl}	Incumbent's number of DSL broadband subscribers (including ADSL, SDSL and VDSL).	Analysys Mason
$cable/other_{bb}$	Sum of cable and other fixed broadband subscribers (including cable, FTTB, FWA and all other fixed broadband connections).	Analysys Mason
$mobile_{bb}$	Number of mobile broadband PC or laptop connections via a USB modem or datacard. Excludes handset access or use of the handset as a modem.	Analysys Mason
pop_{dens}	Population density. Inhabitants per sq. km of land area.	World Bank
ftr	Fixed-to-fixed termination rates in euro PPP.	Progress Reports on Single European Electronic Communications Markets
mtr	Fixed-to-mobile termination rates in euro PPP.	Progress Reports on Single European Electronic Communications Markets

* If not otherwise indicated, data is from 'Telecoms Market Matrix'.

Table A6: Cross-correlation table

Variables	fix_{sub}	mob_{sub}	$voip_{sub}$	p_{fix}	p_{mob}	p_{voip}	bb_{lines}	inc_{mob}
fix_{sub}	1.000							
mob_{sub}	0.911*	1.000						
$voip_{sub}$	0.479*	0.542*	1.000					
p_{fix}	-0.139*	-0.094	-0.010	1.000				
p_{mob}	0.187*	0.014	0.205*	0.498*	1.000			
p_{voip}	0.006	0.027	0.063	0.473*	0.587*	1.000		
bb_{lines}	0.872*	0.924*	0.743*	-0.085	0.149*	0.058	1.000	
inc_{mob}	0.892*	0.971*	0.628*	-0.047	0.105	0.118	0.913*	1.000
gdp_{pc}	0.214*	0.191*	0.267*	0.434*	0.755*	0.557*	0.321*	0.245*
inc_{dsl}	0.890*	0.947*	0.728*	-0.056	0.176*	0.114	0.978*	0.953*
$cable/other_{bb}$	0.205*	0.368*	0.299*	0.058	-0.148*	0.045	0.408*	0.348*
$mobile_{bb}$	0.627*	0.766*	0.459*	-0.118	-0.038	0.077	0.754*	0.726*
pop_{dens}	0.260*	0.316*	0.183*	0.392*	0.237*	0.389*	0.365*	0.315*
ftr	-0.413*	-0.400*	-0.271*	-0.038	-0.179*	-0.041	-0.406*	-0.396*
mtr	-0.063	-0.147*	-0.218*	0.043	0.167*	-0.032	-0.221*	-0.105

	gdp_{pc}	inc_{dsl}	$cable/other_{bb}$	$mobile_{bb}$	pop_{dens}	ftr	mtr
gdp_{pc}	1.000						
inc_{dsl}	0.323*	1.000					
$cable/other_{bb}$	0.157*	0.327*	1.000				
$mobile_{bb}$	0.270*	0.710*	0.379*	1.000			
pop_{dens}	0.376*	0.348*	0.448*	0.169*	1.000		
ftr	-0.283*	-0.390*	-0.164*	-0.384*	-0.142	1.000	
mtr	-0.185*	-0.147*	-0.364*	-0.410*	-0.010	0.284	1.000

$*$: Significant at 5% level or higher.

Table A7: Robustness checks

	Model C			Model D		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	$fix_{sub_{it}}$	$mob_{sub_{it}}$	$voip_{sub_{it}}$	$fix_{sub_{it}}$	$mob_{sub_{it}}$	$voip_{sub_{it}}$
$fix_{sub_{it-1}}$	0.737***			0.790***		
	(0.103)			(0.105)		
$mob_{sub_{it-1}}$		0.581***			0.370**	
		(0.208)			(0.183)	
$voip_{sub_{it-1}}$			1.016***			0.977***
			(0.102)			(0.080)
$p_{fix_{it}}$	-0.203*	0.129	0.141	-0.277*	0.129*	-0.121
	(0.122)	(0.089)	(0.711)	(0.156)	(0.078)	(0.692)
$p_{fix_{it-1}}$	-0.270**	0.081	-0.682	-0.276**	0.106	-0.340
	(0.132)	(0.096)	(0.578)	(0.139)	(0.096)	(0.538)
$p_{mob_{it}}$	0.206**	-0.156*	0.546	0.303**	-0.343***	0.720
	(0.100)	(0.084)	(0.524)	(0.121)	(0.091)	(0.449)
$p_{mob_{it-1}}$	0.201**	-0.015	0.424	0.161**	0.032	0.268
	(0.084)	(0.068)	(0.333)	(0.064)	(0.077)	(0.323)
$p_{voip_{it}}$	-0.017	-0.043***	-0.170**	-0.226	-0.356	0.375
	(0.025)	(0.015)	(0.082)	(0.414)	(0.318)	(0.871)
$p_{voip_{it-1}}$	-0.028	0.018	0.192	-0.039	0.011	0.105
	(0.025)	(0.020)	(0.190)	(0.030)	(0.029)	(0.154)
$inc_{dsl_{it}}$	0.128**	-0.078	-0.045			
	(0.061)	(0.049)	(0.255)			
$cable/other_{bb_{it}}$	-0.052	0.022	-0.023			
	(0.038)	(0.026)	(0.166)			
$mobile_{bb_{it}}$	0.004	-0.013	0.007			
	(0.010)	(0.015)	(0.071)			
$p_{voip_{it}} \# bb_{lines_{it}}$				-0.018	0.025	-0.334
				(0.030)	(0.023)	(0.064)
$bb_{lines_{it}}$				0.117	-0.155	0.334
				(0.206)	(0.155)	(0.438)
$inc_{mob_{it}}$	0.163*	0.119**	0.625*	0.250***	0.069	0.685**
	(0.090)	(0.058)	(0.360)	(0.097)	(0.090)	(0.319)
$gdp_{pc_{it}}$	0.013	0.130***	-0.210	-0.027	0.191***	-0.309
	(0.047)	(0.028)	(0.187)	(0.025)	(0.036)	(0.199)
$pop_{dens_{it}}$	-0.001*	0.001	-0.010	0.000	0.001	-0.006***
	(0.002)	(0.003)	(0.009)	(0.002)	(0.004)	(0.008)
N	120	120	120	120	120	120
Sargan Test χ^2-stat	19.05	17.33	11.16	16.23	19.31	14.06
p-value	0.33	0.43	0.85	0.70	0.50	0.83
AR(4), Prob> z	0.11	0.17	0.56	0.31	0.03	0.52

Significance levels *: 10% **: 5% ***: 1%. Heteroscedasticity robust standard errors in parentheses.
We instrument the lagged dependent and all price variables with their corresponding lags and cost shifters.
Sargan test: H0: Overidentifying restrictions are valid. AR test: H0: No autocorrelation.

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