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Editor:

Prof. Dr. Hans-Theo Normann
Düsseldorf Institute for Competition Economics (DICE)
Phone: +49(0) 211-81-15125, e-mail: normann@dice.hhu.de

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Does the Growth of Mobile Markets Cause the Demise of Fixed Networks? - Evidence from the European Union

Anne-Kathrin Barth* Ulrich Heimeshoff**

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Abstract

The increasing usage of mobile communication and the declining demand for fixed line telephony in Europe make the analysis of substitutional effects between fixed and mobile networks a key aspect for future telecommunication regulation. Using a unique dataset which contains information on all 27 European Union members from 2003 to 2009, we analyze substitutability between fixed and mobile telecommunications services in Europe by applying dynamic panel data techniques. We find strong empirical evidence for substitution from fixed to cellular networks throughout Europe. In addition, the article reveals resulting policy implications.

Keywords: Dynamic Panel Model, Fixed-Mobile Substitution, Telecommunication Markets

*Duesseldorf Institute for Competition Economics (DICE), e-mail: anne-kathrin.barth@dice.uni-duesseldorf.de

**Duesseldorf Institute for Competition Economics (DICE), e-mail: ulrich.heimeshoff@dice.uni-duesseldorf.de

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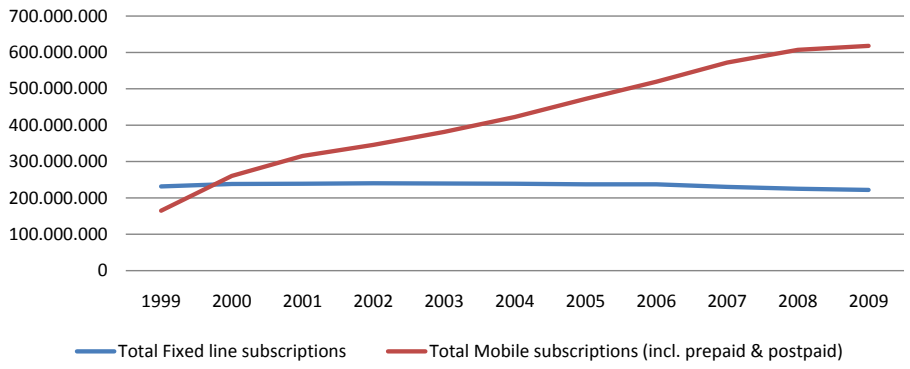
1 Introduction

In the beginning of mobile telephony cellular phones were expensive and technically immature products mainly used by business customers who profited most from "being mobile". Almost every outgoing call went to a fixed phone and incoming calls were primarily originated by fixed networks. Hence, the two technologies were seen as complements, meaning that mobile growth also strengthens fixed line networks (Vogelsang, 2010, p. 5).
After the implementation of GSM digital technology in the early 1990s mobile phones became mass products, demand increased, and prices declined significantly (Hausman 2002; Gruber 2005). This trend changed the situation of fixed and mobile markets considerably. Figure 1 and 2 illustrate the development of the fixed and mobile markets in terms of subscription levels and outgoing voice traffic volumes in the EU27 over time.

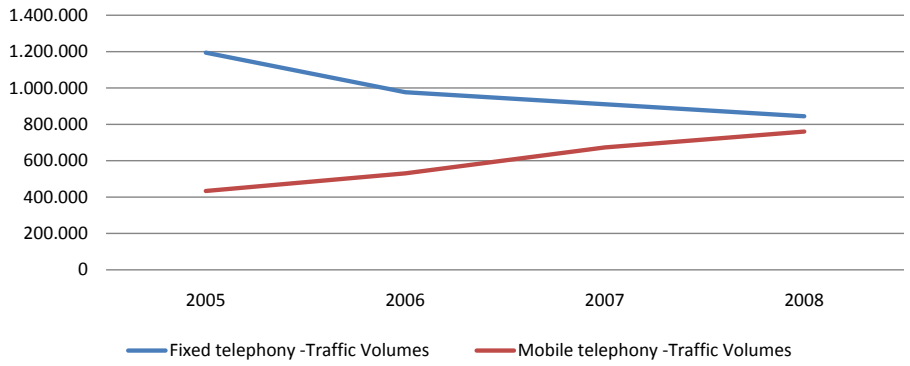
Figure 1: Development of fixed and mobile subscriptions (in total)



Source: ITU 2010

Figure 1 shows that the number of mobile subscribers has exceeded the number of fixed line subscriptions in the European Union since 2000. While the number of total fixed line subscriptions stagnates at a level around 200 million users, the number of mobile subscribers has reached 600 million adopters in 2008 and is still increasing (ITU 2010). Furthermore, figure 2 indicates that the outgoing voice traffic volumes of the fixed and mobile networks are converging, meaning that mobile voice traffic volumes have grown rapidly, whereas fixed traffic volumes went down significantly. Today, the amount of outgoing fixed and mobile voice calls are about the same size, but it is likely that the mobile voice traffic continues to rise and exceeds the fixed voice traffic volumes within the next years (EU Commission, 2010a, p. 26).
Fixed and mobile telecommunication markets are both subject to regulatory obligations (Laffont and Tirole, 2000), but the magnitude of regulation in the two markets is quite different. Through the liberalization of telecommunications markets in Europe, the former state owned telecommunications companies were (partially) privatized and

Figure 2: Development of fixed and mobile outgoing voice traffic (in million of minutes)



Source: EU Commission 2010

new competitors were allowed to enter the markets who had to use the incumbent's infrastructure (Cave and Prosperetti, 2001) due to bottleneck issues. Therefore, fixed telephony markets are regulated to a large extent. In contrast, competition in mobile communication markets was fiercer from its very beginning (Haucap, 2003). Hence, regulation in cellular markets is less restrictive.

The observations of the telecommunications markets in Europe described above lead to the question whether fixed and mobile phones should still be seen as complements or rather as substitutes. If the two services were substitutes, different regulatory arrangements would be hard to justify and the delineation of separate fixed line and mobile electronic communications markets prescribed in the regulatory framework in Europe might be no longer appropriate. Additionally, new regulatory questions would arise: How should a company be treated that exhibits significant market power in fixed line telecommunications, but not in mobile communications? What would be the adequate market definition for antitrust and regulation cases?

Although we observe that fixed line and mobile telephony are converging and becoming closer substitutes, the number of econometric studies has been rather limited. Some first evidence that fixed-mobile substitution is increasing has been provided by Yoon and Song (2003) and Ahn, Lee, and Kim (2004) for Korea and by Rodini, Ward, and Woroch (2003) and Ward and Woroch (2004, 2010) for the USA, by Vagliasindi, Güney, and Taubman (2006) for Eastern Europe, by Heimeshoff (2008) for 30 OECD countries, and by Briglauer, Schwarz, and Zulehner (2011) for Austria. However, there is virtually no econometric paper analyzing fixed-mobile substitution in a multiple EU countries setting. Furthermore, there is hardly any study using recent data, particularly after 2003.

This paper analyzes the demand for telecommunications services in the member states of the European Union on the subscriber level. Using a dataset which comprises information on all 27 EU countries for the time period from 2003 to 2009, we analyze

whether fixed and mobile telecommunications are characterized by a substitutional relationship or not. The main sources of data include the Teligen Reports on Telecoms Price Developments, the Progress Reports on Single European Electronic Communications Markets, the World Development Indicators (WDI), and the ITU World Telecommunication Indicators Database. Our paper is organized as follows: The next section provides an overview of the empirical studies related to fixed-mobile substitution. Afterwards, the dataset used in our empirical study and the econometric approach with respect to panel data are described. The following section 3.3 discusses the main findings and section 4 concludes.

2 Review of the related literature

Although the analysis of fixed-mobile substitution (FMS) is mainly an empirical question, the related econometric literature is not very extensive. Studies merely exist for South Korea, the USA, Portugal, the UK, and some African and Eastern European countries. In addition, recent papers address FMS in India, Austria, and the OECD countries. The following table provides an overview of the existing empirical literature.

Table 1: Empirical Literature on Fixed-Mobile Substitution

Authors	Country	Period
Sung, Kim, and Lee (2000)	South Korea	1991-1998
Yoon and Song (2003)	South Korea	1997-2002
Sung (2003)	South Korea	1993-1997
Ahn, Lee, and Kim (2004)	South Korea	1996-2002
Rodini, Ward, and Woroch (2003)	USA	2000-2001
Ward and Woroch (2004)	USA	1999-2001
Ingraham and Sidak (2004)	USA	1999-2001
Ward and Woroch (2010)	USA	1999-2001
Gruber and Verboven (2001)	140 countries	1981-1995
Barros and Cadima (2002)	Portugal	1981-1999
Horvath and Maldoom (2002)	UK	1999-2001
Madden and Coble-Neal (2004)	56 countries	1995-2000
Hamilton (2003)	Africa (23 countries)	1985-1997
Garbacz and Thompson (2007)	53 LDC	1996-2003
Vagliasindi, Güney, and Taubman (2006)	Eastern Europe	2002
Heimeshoff (2008)	OECD (30 countries)	1990-2003
Narayana (2008)	India	2003
Briglauer, Schwarz, and Zulehner (2011)	Austria	2002-2007

Using panel data for the period 1991-1998 for 8 South Korean provinces, Sung, Kim,

and Lee (2000) find that a 1% increase in the number of mobile phones results in a 0.1-0.2% reduction of fixed line connections. Thus, they conclude that fixed and mobile telephones are substitutes on Korean telecommunications markets. In more detail, the number of mobile subscribers is positively related with the number of fixed line disconnections, but negatively related to the number of new fixed line connections, which suggests net substitution between fixed and mobile services. Yoon and Song (2003) study fixed-mobile substitution in South Korea by analyzing monthly traffic and revenue data from 1997 to 2002. They find that fixed and mobile calls are substitutes and fixed-mobile convergence can be observed in South Korea as in other states of the world. Sung (2003) reports that mobile calls are substitutes for fixed line toll calls by using Korean regional panel data for 1993-1997. Using traffic data from 1996 to 2002 for South Korean telecommunications markets, Ahn, Lee, and Kim (2004) approve these results.

Rodini, Ward, and Woroch (2003), Ward and Woroch (2004), Ingraham and Sidak (2004), and Ward and Woroch (2010) show the existence of substitutability between fixed and mobile networks in the USA by using the same US survey data for the time period 1999 to 2001. Rodini, Ward, and Woroch (2003) analyze the substitutability between fixed and mobile access in the USA modeling the consumers wireless and second fixed line subscription decision (with logit regressions). They estimate own and cross-price elasticities finding substitution effects. Ward and Woroch (2004) report comparable effects applying the Almost Ideal Demand System-Model (AIDS) (Deaton and Muellbauer, 1989, p. 75-80). They conclude that mobile services are substitutes for fixed line usage at the traffic level, but not at the access level. It should be noted that they only find a moderate degree of substitutability and further empirical evidence is needed to strengthen this hypotheses. Ingraham and Sidak (2004) analyze the effect of long-distance fixed line call prices on mobile demand and report a small, but highly significant cross-elasticity of +0.022 adopting least squares and 2SLS regression. Ward and Woroch (2010) estimate cross-price elasticities between fixed and mobile subscription by making use of US low-income subsidy programs (Lifeline Assistance) which cause large changes in the fixed line prices. Although they use the identical US survey data, the elasticities found are larger than those for second lines in Rodini et al.(2003). Due to their ability of generating more price variation by the incorporation of subsidy programs, they are able to estimate demand relationships.

Gruber and Verboven (2001) infer from their study, comprising data of 140 countries from 1981-1995, that the diffusion of mobile phones tends to be larger in countries with higher fixed network penetration. Therefore, they conclude that the two technologies are complements. Barros and Cadima (2002) analyze time series data on fixed and mobile access in Portugal from 1981 until 1999. They identify a negative effect of mobile phone diffusion on fixed line penetration rates, but none vice versa. Horvath and Maldoom (2002) study survey data on over 7,000 British telephone users (repeated cross section in three waves: 1999, 2000, 2001) in a simultaneous equations model and additionally estimate some probit regressions. They induced from their study that

using mobile phones decreases fixed line usage significantly. Their findings support the conclusion that fixed and mobile phones are substitutes in British telecommunications markets. Madden and Coble-Neal (2004) examine FMS in 56 countries between 1995-2000 in a dynamic demand model and assess significant substitution effects between mobile and fixed line subscription rates.

Hamilton (2003) uses annual data from 1985-1997 representing 23 African countries. The econometric study shows that fixed and mobile phones in many African countries are still no substitutes. Hamilton argues that the usage of mobile phones does not reduce fixed line usage, but is primarily an improvement in social status. Compared to studies concentrating on developed countries, these results are not surprising, because in countries that lack an extensive fixed line infrastructure, like many African and other low developed countries, mobile phone usage is often a result of a lack of supply. In such cases mobile phones are often the only means of access to a telephone.

Vagliasindi, Güney, and Taubman (2006) observe substitutional relationships between fixed and mobile services for Eastern European countries using cross section data for several countries in 2002. In contrast to the other studies, the authors use cross section instead of panel data and cannot control for unobserved heterogeneity. Garbacz and Thompson (2007) analyze FMS in 53 low developed countries (LDC) finding asymmetric substitutional effects. Fixed connections tend to be substitutes in the mobile market, whereas mobile phones might be complements in the fixed line market. Overall, investigating substitutional effects between fixed and mobile services in transition countries is always difficult as the low quality of fixed networks in these countries often does not allow fixed-mobile substitution. Instead, mobile phones are often the only possibility to receive access to telecommunications.

Heimeshoff (2008) studies FMS on the access level and estimates cross-price elasticities in 30 OECD countries between 1990 and 2003 by using IV estimation. Possible endogeneity problems are solved by instrumenting fixed and mobile prices and the variable measuring market structure with instrumental variables related to costs and policy indicators. Some sort of one-way substitution is found, i.e. mobile telephony can be a substitute to fixed line services, but not vice versa.

FMS on the subscription level in India is analyzed by Narayana (2008) using cross sectional survey data for 2003. He includes subscription prices as well as usage prices as explanatory variables in his regression and finds that both prices are correlated and that the usage price has, in comparison to the subscription price, a much larger and more significant effect on the mobile and fixed line subscription. Narayana finds much stronger substitutional effects in both directions than other studies, but uses only cross-sectional data for 2003 and therefore cannot control for unobserved heterogeneity. Employing monthly data on call minutes and taking average revenues per minute as price data, Briglauer, Schwarz, and Zulehner (2011) estimate short- and long-run cross-price elasticities for fixed line domestic calling in response to mobile price changes in Austria for 2002 to 2007. While they observe small and sometimes insignificant estimates for short-run elasticities, their results for long-run cross-price elasticities suggest

strong substitution effects.
Beside these econometric studies, some papers of European regulators also discuss the issue of fixed-mobile substitution. Griffith and Dobardziev (2003) conclude for the Netherlands that there already exists some degree of substitutability and this process will proceed as mobile call prices will continue to fall. For Germany, Wengler and Schäfer (2003) evaluate the findings of a telephone survey consisting of 1691 persons (first wave), 2014 persons (second wave) and 101 persons (third wave) collected in March and April 2003. They only observe a very moderate tendency for fixed-mobile substitution in Germany in 2003 and most of the survey participants argue that they do not substitute between their fixed line and mobile phones. As a consequence, there is no clear empirical evidence which kind of relationship holds between fixed and mobile telephony. It can be concluded that there is to the best of our knowledge no empirical study on the subscription level which uses recent data, i.e. data after 2003. It is likely that the substitutional effects of fixed-mobile substitution are much larger nowadays, e.g. due to further price reductions in mobile markets. In addition, it should be noted that there is no multiple country study focusing on fixed-mobile substitution in all 27 EU countries. The following sections provide an overview of the data set and the applied econometric approach of our empirical study.

3 Empirical Specification

3.1 Data

Our data is obtained from the following resources: the Teligen Reports on Telecoms Price Developments, the Progress Reports on Single European Electronic Communications Markets, the ITU World Telecommunications Indicators Database, and the World Development Indicators (WDI). Additionally, the MTR Snapshots of BEREC are used. We analyze substitutional effects on private access level in all EU member states[1] from 2003-2009. Table 2 illustrates the descriptive statistics for all variables used. Fix_{sub} describes the number of total fixed line subscribers, whereas mob_{sub} comprises the number of mobile subscribers in an EU27 country including prepaid as well as postpaid subscriptions. P_{mob} represents the average mobile price per call for a given user calculated by using the OECD/Teligen baskets of mobile telephony[2]. P_{fix} is the average fixed line price per call constructed by using the residential composite OECD basket (2000 version)[3]. $Internet_{sub}$ describes the number of fixed line Internet subscribers (all technologies) and mtr the mobile termination rates. The control variable gdp_{pc} refers to the GDP per capita. Pop measures population in a specific

[1]During the regarded time period new members entered the European Union. Until 2004, the EU consisted of 15 members. In 2004, the EU was enlarged to 25 members. In 2007, Bulgaria and Romania joint the EU.

[2]See appendix for detailed information

[3]See appendix for detailed information

Table 2: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
fix_{sub}	189	8,623,152	12,900,000	202,116	54,800,000
gdp_{pc}	189	22,642.14	11,636.47	3432.61	69,334.23
$Internet_{sub}$	178	3,895,888	6,016,454	47,011	34,400,000
mob_{sub}	189	19,000,000	24,900,000	289,992	106,000,000
mtr	185	0.1272	0.0664	0.0218	0.3829
p_{fix}	188	0.3573	0.0998	0.1935	0.6738
p_{moblow}	171	0.5042	0.2339	0.0574	1.1147
p_{mobmed}	171	0.3885	0.1583	0.1008	0.7757
$p_{mobhigh}$	171	0.3386	0.1462	0.0827	0.7215
$perc_{prepaid}$	187	0.5554	0.1911	0.0250	0.9301
$perc_{urban}$	189	0.7128	0.1203	0.4830	0.9738
pop	189	18,200,000	22,600,000	397,399	82,400,000
$time$	189	4	2.0053	1	7

country. $Perc_{urban}$ depicts the percentage of the population which lives in urban areas and $perc_{prepaid}$ describes the percentage of prepaid contracts. $Time$ is a linear time trend. The time trend can be interpreted as a constant upgrade in the service quality, the increase in the availability of services, and the enhanced network performance as well as decreasing prices (see Grzybowski, 2005). All price variables (p_{mob}, p_{fix}, mtr, gdp_{pc}) and the subscription variables mob_{sub} and fix_{sub} are measured in logarithms in order to interpret them as elasticities. Additionally, all price variables are measured in Euro adjusted by purchasing power parities to add in international comparison. The following subsection explains our model specification.

3.2 Model

Fixed-mobile substitution can be analyzed on three different levels: subscribers, traffic, and revenues (ITU, 2010). To analyze the substitutability between products, usually short- and long-run elasticities are estimated (Taylor, 1994). Such studies belong to the traffic or usage level. However, there is no separate information about traffic data for fixed line telecommunications available for most European countries. Instead, we estimate the effects of several explanatory variables, particularly prices and the first lag of the dependent variable, on the stocks of mobile and fixed line subscriptions. A standard approach to estimate demand equations in telecommunications markets can be derived from the well known Houthakker-Taylor model (see Houthakker and Taylor, 1970). The main characteristic of the Houthakker-Taylor model is the inclusion of path dependencies in consumption into the demand equation, which are represented in the demand equation by lagged dependent variables. Taking the panel structure of our data and country specific effects into account, we can derive two adequate specifications.

Equation (1) and equation (2) study the effects of certain variables on the mobile and fixed line subscription rate, respectively.

$$mob_{sub_{it}} = \beta_1 mob_{sub_{it-1}} + \beta_2 p_{mob_{it}} + \beta_3 p_{mob_{it-1}} + \beta_4 p_{fix_{it-1}} + \sum \beta_k x_{itk} + \alpha_i + \epsilon_{it} \quad (1)$$

We expect $mob_{sub_{it-1}}$ to have a positive influence on the current mobile subscription rate for the simple reason that if there were more subscribers yesterday, there will be more subscribers today. Including the first lag of the dependent variable is one way to model the persistence in the subscriber series. We assume that the mobile subscription rate today depends on the current mobile price and its first lag due to different tariff structures in terms of contract durations and subscription fees. Several mobile tariffs include contract durations. Therefore, it is reasonable that a cancellation of a contract as a response to a (relative) price change is delayed. Furthermore, other tariffs do not include a contract duration or monthly subscription fee. Thus, the current price does also influence the current level of the mobile subscription rate due to the possibility of a quick cancellation or the conclusion of a second contract. Both own-price elasticities are supposed to have a negative impact on the mobile subscription rate, meaning that an increase in the own price leads to a decrease in the number of subscribers. In order to find substitutional effects, the fixed line price must have a positive effect on mob_{sub}. We employ the first lag of the fixed line price, as we assume that fixed to mobile substitution on access level can be seen as a quite slow process. One possible explanation is that fixed lines are usually used by households, and not by individuals. Therefore, the cancellation of the fixed line access affects all family members. Hence, the reaction to a change in price will be delayed and will then not depend on the current price, but on the former fixed line price. The term $x_{it,k}$ includes all additional explanatory variables such as GDP, the population size, fixed line Internet subscribers, percentage of urban population and prepaid users. ϵ_{it} is an error term and α and the βs are parameters to be estimated.

Checking for reverse substitution effects, i.e. from mobile towards fixed line networks, we re-estimate equation (1) by replacing the variable mob_{sub} with fix_{sub}. Although it is possible to find substitutability towards fixed technologies, we have to keep in mind that fixed line phones can never be a full substitute for mobile devices due to its lack of mobility. In addition to that, the cancellation of a fixed line contract is more complex since a fixed line access is related to a whole household and usually not to an individual. Furthermore, households will not have more than one contract as it would be possible for mobile phones. Thus, we assume that the fixed line subscription does not depend on the current own price, but on the former fixed line price. Again, to find substitution effects from mobile towards fixed line networks, we need to find positive cross-price elasticities. We include the current mobile price as well as the lagged mobile price. Since we argue that people will only have one fixed line contract, the conclusion of a new fixed line contract will only be done by former mobile-only consumers.

$$fix_{sub_{it}} = \beta_1 fix_{sub_{it-1}} + \beta_2 p_{fix_{it-1}} + \beta_3 p_{mob_{it}} + \beta_4 p_{mob_{it-1}} + \sum \beta_k x_{itk} + \alpha_i + \epsilon_{it} \quad (2)$$

We expect $fix_{sub_{it-1}}$ to have a positive influence on current fixed line subscription rates for the simple reason that if there were more fixed line subscribers yesterday, there will be more subscribers today. Again, this is the persistence argument which also holds for the mobile subscribers series. We suppose that the own-price elasticity is negative. In order to find substitutional effects, the mobile prices must have a positive effect on fix_{sub}. The term $x_{it,k}$ again includes all additional explanatory variables such as GDP, the population size, fixed line Internet subscribers, percentage of urban population and prepaid users. ϵ_{it} is an error term and α and the βs are parameters to be estimated.
Controlling for unobserved heterogeneity and endogeneity problems due to our dynamic setup, we apply the one-step System GMM estimator suggested by Arellano and Bover (1995), Blundell and Bond (1998), and Blundell, Bond and Windmeijer (1998), which is an extension of the estimator developed by Arellano and Bond (1991). In addition to the inclusion of lagged levels and differences of dependent variables as instruments for our lagged dependent and endogenous variables, we also incorporate further instruments to solve possible endogeneity problems. We restrict the maximal number of lags to two. It is well known from the econometrics literature that Arellano-Bond type estimators perform relatively poor in small samples. Following Blundell, Bond and Windmeijer (1998), including additional moment conditions helps significantly to overcome the finite sample bias. Additionally, we apply the system GMM estimator which does not only improve the precision but also reduces the finite sample bias problem. The good performance of system GMM estimators in finite sample settings is also confirmed by recent simulation studies (see Soto, 2010).
Preventing spurious regressions, we apply panel unit root tests for all variables in our data set. The results of the test statistics can be found in table 12 in the appendix. We find that three of our independent variables, gdp_{pc}, $perc_{urban}$ and mtr, are integrated of second order or higher.[4] However, our GMM estimator applies a first differences transformation, ensuring that non-stationary variables could not cause spurious regression problems because our left-hand side variables are stationary after applying first-differences. Furthermore, cointegration relationships cannot be present in our dataset, because we do not have identical orders of integration on the left-hand side and the right-hand side of our equations.
Some additional remarks should be presented due to the estimation of our system of equations. We apply single equation techniques to estimate the fixed- and mobile-equations, because generally single equation estimators as 2SLS are more robust than simultaneous multiple equation estimators as for example 3SLS. The main advantage of system estimators is their improved efficiency compared to single equation estimators. But there is an important requirement for such efficiency gains: all equations in the system have to be specified correctly. Single equations methods as 2SLS estimate one equation of the system consistent and asymptotically normal, when the equation is

[4]For further information see Hamilton (1994).

specified correctly and the instruments work quite well. The most important weakness of estimators as 3SLS and simultaneous GMM estimators is their property that if one equation in a system is misspecified, all parameter estimates of the system are inconsistent[5]. As a result, misspecifications in one equation spill over to the estimates of the other equations of the system. The following section provides our main estimation results as well as their interpretation.

3.3 Empirical Results

In order to solve possible endogeneity problems, we instrument the fixed and mobile call prices with termination rates. We include the current mobile termination rates as well as its first lag. Termination rates are an important (variable) cost factor for the mobile operators which occur particularly for off-net calls. The national regulatory authorities in each country determine the termination charges which can therefore be considered as exogenous. This assumption can be criticized as the decision of the regulator may be affected by other factors such as changes in volumes. Nevertheless, termination rates are the only cost shifter which directly influences the variable costs and can be observed by an econometrician. By applying Sargan tests, we test for the exogeneity of our instruments and we cannot reject the null hypothesis stating exogeneity of our instruments (Briglauer et al., 2011, p. 13). Table 3 illustrates our results.[6] For the regression on mobile subscriptions (equation(1)), we identify statistically significant effects at a 5% or higher significance level from the first lag of mobile subscription, the current mobile price, the lagged fixed line price and population. All significant variables have the expected signs. The lag of mobile subscription has a large positive effect on the current mobile subscription which is significant at a 1% significance level. The own-price elasticity is negative as expected. The beta coefficient of the lagged fixed line price is +0.1915 which indicates that a 1% increase in the lagged fixed line price would lead to a 0.1915% increase in the current mobile subscription rate. One should note that this finding is an indicator of fixed-mobile substitution on the subscriber stage. Furthermore, the magnitude of the cross-price elasticity found is in range with previous empirical findings. But comparisons should be done with caution because other papers are using different datasets and estimation methods. In addition, population has a significantly positive effect on mobile subscription.

For the regression on fixed line subscriptions (equation (2)), we only find significant effects for the first lag of fixed line subscription and its own price, both on a 1% significance level. In addition, GDP per capita is significant on a 10% level. Again, all significant variables have the expected signs.

Overall, our findings provide evidence for one-way-substitution. One can substitute a

[5]For further discussion see Wooldridge (2010).

[6]Due to multicollinearity problems, we cannot include all 3 mobile call prices into our regression. Instead, we use the mobile call price for low users because of its larger variation. But, we also estimated our model including the medium or high usage price. The results are reported in the appendix.

fixed line phone by a mobile phone, but mobile phones are only partially substitutable by fixed line phones, because of the lack of mobility. One should note that the result of one-way-substitution is in line with the earlier findings in Heimeshoff (2008).

Table 3: Estimation results for EQ(1) and EQ(2)

Variable	Mob_{sub}	Fix_{sub}
$L.mob_{sub}$	0.8947***	
	(0.0458)	
$L.fix_{sub}$		0.9631***
		(0.0248)
$L.p_{fix}$	0.1915**	-0.1296***
	(0.0818)	(0.0499)
p_{mob}	-0.1610**	-0.0054
	(0.0687)	(0.0298)
$L.p_{mob}$	0.0683	0.0080
	(0.0434)	(0.0311)
gdp_{pc}	0.0092	0.0366*
	(0.0571)	(0.0218)
pop	1.055e-08**	2.39E-09
	(0.0000)	(0.0000)
$Internet_{sub}$	-1.20E-08	7.62E-10
	(0.0000)	(0.0000)
$perc_{prepaid}$	-0.0630	0.0595
	(0.1257)	(0.0662)
$perc_{urban}$	-0.0475	-0.1394
	(0.2999)	(0.1661)
$time$	-0.0145	-0.0031
	(0.0092)	(0.0031)
$cons$	1.7754*	0.0696
	(1.0686)	(0.4502)
$chi2$	1392.9548	10353.505
N	134	134

*,**,*** indicate statistically significant on the 10%-, 5%-, and 1%-level
Heteroscedasticity robust standard errors in parenthesis
Endogenous variables: $L.mob_{sub}$, $L.fix_{sub}$, p_{fix}, p_{mob}
Instrumental variables: $lmtr_{ppp}$, $L.lmtr_{ppp}$

In addition, we run different specification tests. First of all, we apply the Arellano-Bond test for zero autocorrelation in first-differenced errors. We find first order autocorre-

lation[7], but no second order autocorrelation in both regressions (with p-values of 0.27 and 0.7071). Furthermore, the Sargan test indicates the validity of our specifications (Table 4).

Table 4: Sargan test of overidentifying restrictions

	Equation(1)	Equation(2)
$chi2(32)$	36.2051	41.5229
$Prob > chi2$	0.2787	0.2077

H0: overidentifying restrictions are valid

Our empirical findings suggest a fixed line own-price elasticity of -0.1296 and a mobile own-price elasticity of -0.1610, which indicates that the mobile demand is more elastic than the demand for fixed line subscription. The cross-price elasticity of the mobile price is insignificant, whereas the cross-price elasticity of the fixed line price is +0.1915. Thus, our study confirms modest one-way substitution from fixed to mobile services on the access level. But with the evolution of new mobile services and especially high-speed mobile Internet, the magnitude of fixed-mobile substitution will likely increase. The following section concludes and provides some discussion of policy implications.

4 Conclusion and Policy Implications

Our paper has analyzed fixed-mobile substitution on the basis of the relationship between fixed and mobile subscriptions in the European Union. The main problem in studying fixed-mobile substitution and mobile phone usage in most European Union countries is the unavailability of traffic data disaggregated for fixed line telecommunications services. To avoid these difficulties we have used the numbers of fixed and mobile subscriptions in each country and have estimated effects of price changes of the respectively other product on fixed and mobile penetration rates. Studying 27 EU countries from 2003-2009, we find evidence for substitutability of fixed and mobile services, but have some problems of endogeneity in our econometric model which are solved by instrumenting prices with termination rates. However, one has to note that we only find one-way-substitution, because cellular phones usually cannot be substituted completely by fixed line devices.

With regard to regulation of telecommunications markets fixed-mobile substitutability has a wide ranging impact. Most mobile telecommunications markets in Europe are not very strongly regulated, an observation which holds for most parts of the world

[7]Because the first difference of independently and identically distributed idiosyncratic errors will be autocorrelated, rejecting the null hypothesis of no serial correlation at order one in the first-differenced errors does not imply that the model is misspecified. Rejecting the null hypothesis at higher orders implies that the moment conditions are not valid.

(Nuechterlein and Weiser, 2005, p. 261). Exceptions are issues like mobile number portability, mobile termination rates, and international roaming. In contrast, fixed telecommunications markets are subject to considerable regulatory obligations. These different approaches have been quite reasonable when mobile communications services were very expensive and only available for a small number of customers. Today, decreasing prices and the growing substitution between fixed and mobile services raise the question whether two different regulatory regimes for fixed and mobile markets are still appropriate. Consider the verification of significant market power: If fixed and mobile services are substitutes, it is not sufficient that a telecommunications company has significant market power (or a main share of the market) in the market for fixed line services because customers use mobile services as substitutes to the company's fixed line services and are not constrained to fixed line telephony. As a result, it would be difficult to appropriate rents as a consequence of significant market power in fixed or mobile markets only. If the evolution of usage patterns suggests that mobile telecommunications services constrain fixed line companies' market power, regulatory obligations on fixed telephony markets have to be reconsidered (Rodini, Ward, and Woroch, 2003, p.475). In conjunction with these developments the suitability of the definition of separate fixed and mobile markets in the current European regulatory framework may need to be reconsidered for future telecommunications regulation. On the other hand, there are other aspects besides the convergence of fixed and mobile networks, which will affect the development of telecommunications markets fundamentally. One of these aspects is the market success of voice telephony over Internet protocol (VoIP) (Majumdar, Vogelsang, and Cave, 2005). If VoIP becomes the industry standard for voice telephony, services of classical fixed and mobile networks could be substituted by VoIP and different forms of networks will converge. An interesting subject for future research is the impact of increasing availability as well as quality and security of VoIP on the number of fixed and mobile subscriptions. In Germany as well as in other European countries the availability of appropriate data is always problematic. In transition or developing countries the situation is very different as a result of the poor fixed line infrastructure and the corresponding low growth rates. Growth rates of mobile communications are much higher than growth rates of fixed networks in these countries. As a consequence, we will observe other forms of network convergence than in developed countries. The future development and regulation of telecommunications markets will remain an important field of research, particularly because of technological change which will be a key aspect for fixed-mobile substitution and the meaning of telecommunications for economic growth and development (Munnell, 1992; Norton, 1992; Röller and Waverman, 2001).

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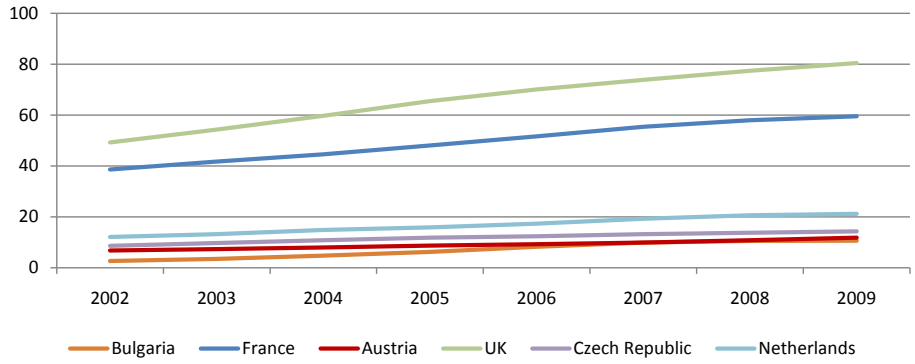
5 Appendix

Table 5: Description of the variables used

Variable	Description of variables
fix_{sub}	Total number of fixed line subscribers
gdp_{pc}	GDP per capita in Euro
$Internet_{sub}$	Total number of Internet subscribers
mob_{sub}	Total number of mobile subscribers (prepaid + postpaid)
mtr	Mobile termination rates in Euro
p_{fix}	Price of an average fixed line call (in Euro)
p_{mob}	Price of an average mobile call (in Euro)
$perc_{prepaid}$	Percentage of prepaid contracts in relation to all mobile contracts
$perc_{urban}$	Percentage of urban population
pop	Population
$time$	Linear time trend

Figure 3: Development of mobile subscription rates (in millions) in selected Western and Eastern European countries



Source: ITU 2010

Table 6: Member States of the European Union

Country	Period	Country	Period
Austria	2003-2009	Latvia	2004-2009
Belgium	2003-2009	Lithuania	2004-2009
Bulgaria	2007-2009	Luxembourg	2003-2009
Cyprus	2004-2009	Malta	2004-2009
Czech Republic	2004-2009	Netherlands	2003-2009
Denmark	2003-2009	Poland	2004-2009
Estonia	2004-2009	Portugal	2003-2009
Finland	2003-2009	Romania	2007-2009
France	2003-2009	Slovakia	2004-2009
Germany	2003-2009	Slovenia	2004-2009
Greece	2003-2009	Spain	2003-2009
Hungary	2004-2009	Sweden	2003-2009
Ireland	2003-2009	UK	2003-2009
Italy	2003-2009		

Methodology of the Teligen/OECD Price Baskets

Combining a certain usage profile with relevant tariffs, each Teligen/OECD price basket describes a theoretical user based on research supported by operators in a large number of OECD countries to enable international comparisons. The following tables 8 and 9 summarize the main properties of the baskets (2002 version).

Table 7: Main Properties of the Residential Basket (Version 2000), calls per year

	National calls	International calls	Calls to mobile
Residential basket	1200	72	120

Table 8: Main Properties of the Mobile Baskets (Version 2002), calls per year

	Outgoing calls	SMS	To Mobile	To Fix
Low	300	360	58%	42%
Medium	900	420	64%	36%
High	1800	504	60%	40%

Each basket also assumes a unique definition of time of day and call duration and contains components for fixed fees and usage in terms of voice and messages. Taking SMS prices from the OECD Communication Outlook 2009, we calculate costs of text messages. For the remaining six countries which do not belong to the OECD, we use

average SMS prices of the included OECD countries. In order to calculate call prices, we subtract the calculated SMS costs from the total costs of each basket. Then, our baskets only contain costs related to voice calls and subscription fee. Therefore, we divide the annual costs of each specific basket by the assumed calls per year and use these average prices in our analysis. In order to derive the fixed line price, we just divide the total costs of the residential basket by the amount of assumed calls.

Table 9: Pairwise Correlation between variables

	p_{fix}	p_{mob}	gdp_{pc}	$time$
p_{fix}	1.0000			
p_{mob}	0.3374*	1.0000		
gdp_{pc}	-0.5689*	-0.2207*	1.0000	
$time$	-0.0113	-0.3454*	0.2073*	1.0000
pop	-0.0614	0.3360*	0.0726	0.0055
$Internet_{sub}$	-0.1664*	0.2413*	0.2052*	0.0734
$perc_{prepaid}$	0.2987*	0.4135*	-0.1332	-0.1312
$perc_{urban}$	-0.3086*	-0.0007	0.4920*	0.0246
	pop	$Internet_{sub}$	$perc_{prepaid}$	$perc_{urban}$
pop	1.0000			
$Internet_{sub}$	0.9099*	1.0000		
$perc_{prepaid}$	0.069	0.0451	1.0000	
$perc_{urban}$	0.1392	0.2411*	0.0282	1.0000

* significant on 5% level or higher

Table 10: Correlation between fixed and mobile prices and mobile termination rates

	p_{mob}	$L.p_{mob}$	$L.p_{fix}$
mtr	0.6098*	0.5955*	0.6109*
L.mtr	0.5748*	0.5867*	0.5883*

* significant on 5% level or higher

Table 11: Empirical Results for EQ(1) with different mobile prices

Variable	Mob_{sub}		
p_{mob}	Low Usage	Medium usage	High usage
$L.mob_{sub}$	0.8947***	0.9138***	0.9468***
	(0.0458)	(0.0513)	(0.0424)
$L.p_{fix}$	0.1915**	0.1736**	0.1590**
	(0.0818)	(0.0804)	(0.0811)
p_{mob}	-0.1610**	-0.0337	-0.0378
	(0.0687)	(0.0550)	(0.0448)
$L.p_{mob}$	0.0683	0.0497	0.0712
	(0.0434)	(0.0575)	(0.0455)
gdp_{pc}	0.0092	0.0072	0.0113
	(0.0571)	(0.0530)	(0.0511)
pop	1.055e-08**	8.347e-09*	6.588E-09
	(0.0000)	(0.0000)	(0.0000)
$Internet_{sub}$	-1.20E-08	-1.33E-08	-1.21E-08
	(0.0000)	(0.0000)	(0.0000)
$perc_{prepaid}$	-0.0630	-0.0671	-0.0775
	(0.1257)	(0.1723)	(0.1648)
$perc_{urban}$	-0.0475	0.1335	0.1823
	(0.2999)	(0.2646)	(0.2027)
$time$	-0.0145	-0.0037	-0.0060
	(0.0092)	(0.0122)	(0.0104)
$cons$	1.7754*	1.4364	0.8825
	(1.0686)	(1.0711)	(0.8087)
$chi2$	1392.95	2351.30	4594.13
N	134	134	134

*,**,* * * indicate statistically significant on the 10%-, 5%-, and 1%-level
Heteroscedasticity robust standard errors in parenthesis
Endogenous variables: $L.mob_{sub}$, $L.fix_{sub}$, p_{fix}, p_{mob}
Instrumental variables: $lmtr_{ppp}$, $L.lmtr_{ppp}$

Table 12: Maddala-Wu Unit Root Tests

	Levels	First differences
mob_{sub}		
$chi2$	40.9792	77.4336
$Prob > chi2$	0.9041	0.0200
fix_{sub}		
$chi2$	47.9354	189.9100
$Prob > chi2$	0.7061	0.0000
p_{fix}		
χ^2	163.6148	132.1633
$Prob > \chi^2$	0.0000	0.0000
p_{mob}		
$chi2$	30.9646	93.9217
$Prob > chi2$	0.9950	0.0002
gdp_{pc}		
$chi2$	3.1671	1.3283
$Prob > chi2$	1.0000	1.0000
pop		
$chi2$	170.4307	96.9878
$Prob > chi2$	0.0000	0.0003
$internet_{sub}$		
$chi2$	115.0975	149.4541
$Prob > chi2$	0.0000	0.0000
$perc_{prepaid}$		
$chi2$	63.2590	71.1455
$Prob > chi2$	0.1820	0.0589
$perc_{urban}$		
$chi2$	28.4259	5.1719
$Prob > chi2$	0.9984	1.0000
mtr		
$chi2$	24.4345	43.0712
$Prob > chi2$	0.9998	0.8570

Ho: unit root

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Heinrich-Heine-University of Düsseldorf

Düsseldorf Institute for Competition Economics (DICE)

Universitätsstraße 1 _ 40225 Düsseldorf
www.dice.hhu.de

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