Fixed-to-Mobile Substitution in the European Union *

Lukasz Grzybowski†

Abstract

This paper analyzes substitution between access to fixed-line and mobile telephony in the European Union in years 2005-2010. We estimate a structural model of household's demand for access to: (i) fixed-line only; (ii) mobile only; (iii) and both fixed-line and mobile. We find that decreasing prices for mobile services increase the share of 'mobile only' households and decrease shares of 'fixed only' and 'fixed + mobile' households which suggests substitution between fixed-line and mobile connections. Moreover, growing Internet usage increases the share of 'fixed + mobile' households, which suggests that households keep their fixed line connection to access Internet. However, spread of 3G and cable modem broadband access decreases the share of 'fixed + mobile' households and increases the share of 'mobile only' households. Hence, fixed-line connection used for Internet access may be substituted by mobile broadband in the future. On the other hand, bundling increases the share of 'fixed + mobile' households and decreases the shares of 'mobile only' and 'fixed only' households, which suggests that operators which provide both fixed-line and mobile services may slow down the substitution by bundling these services.

Keywords: Fixed-To-Mobile Substitution; Fixed Broadband; Mobile Broadband

JEL Classification: L13, L43, L96

---

*The financial support provided by the Economic Research Southern Africa (ERSA) is acknowledged. All errors are mine.

†Telecom ParisTech, Department of Economics and Social Sciences, 46 rue Barrault, 75013 Paris, France & School of Economics, Faculty of Commerce, University of Cape Town, Private Bag, Rondebosch 7701, Cape Town, South Africa. E-mail: lukasz@mushroomski.com

1 Introduction

Over the past few years, the incumbent operators in most EU countries have seen a decline in their fixed-line business as consumers have increasingly used mobile phones to communicate. Deteriorating voice revenues from fixed-line telephony require telecommunications regulators to analyze fixed-to-mobile substitution (FMS) and take it into account in setting access charges.[1] Also, the competition authorities must take into account the extent of substitutability between mobile and fixed-line when carrying out antitrust investigations into telecommunications markets. The relationship between fixed-line and mobile technologies is therefore an important research question and there is a growing body of empirical literature on this topic.

In general, empirical findings on FMS are mixed. Fixed-line and mobile telephony was found to be complementary in developed countries in the early years of mobile telephony. At this stage, when the prices for the usage of mobiles were relatively high as compared to fixed-line usage, consumers perceived mobile and fixed-line access as complements. They wanted to enjoy the benefits of having a mobile access but used fixed-line for making calls whenever possible. Hence, after getting a mobile phone they were not giving up fixed-line access. On the other hand, there is evidence on substitutability in developing countries where fixed-line infrastructure is poor or mobile phones are often the only communications technology available, and in developed countries in the mature years of mobile telephony. In the later stage of development of mobile telephony, with decreasing prices for mobile calls, consumers started to substitute mobile and fixed-line usage to a greater extent. Over time, low prices for mobile calls and higher utility from having a mobile phone, made fixed-line obsolete and consumers started to give up fixed-line

[1] In the UK, for instance, the telecommunications incumbent British Telecom is obliged to assess the level of its non-domestic rates liability every five years. The rates are set using the methodology of profit based value (PBV), for which one of the critical inputs are the forecasts of the future development and usage volumes of telecommunications services. The substitutability between different technologies, including FMS, plays a critical role in producing these forecasts. If the FMS is underestimated, the business rate may be set too low negatively affecting profitability of the incumbent. On the other hand, if it is overestimated, the business rate may be set too high with negative consequences for competition and consumers.

connections.[2] However, the extent of FMS has been also affected by a rapid growth in Internet usage and broadband access. The majority of Internet connections still relies on copper lines which could have slowed down FMS.[3]

In a recent literature review, Vogelsang (2010) discusses gaps in research on FMS. More research is needed into behavior of 'mobiles only' households. Also, the effects of broadband adoption on FMS need to be analyzed. In particular, one would like to know if Internet adoption is limiting FMS and if adoption of mobile and other broadband technologies is increasing FMS.

Within the European Union there is a large variation in the extent to which households use fixed-line only, mobile only or both telecommunications services. There may be many potential reasons for this such as the regulatory measures in place, the maturity of market, the coverage of fixed networks and timing of development of mobile networks as well as the type of adopted broadband technologies. Also, an increasing number of operators offer bundles including fixed and mobile telephone connections, broadband access and IPTV.[4] According to Eurobarometer, in March 2011, 42% of European households declared that they bought two or more communication services as part of a bundle, see Eurobarometer (2011). Even though FMS is an issue of critical importance for regulators, there is no recent empirical analysis of FMS in the EU countries.

This paper analyzes substitutability between fixed-line and mobile telephony in 27 EU countries in years 2005-2010 using cross-country panel data on households' choices of telecommunications technologies. We estimate household's demand for access to: (i) fixed-line only; (ii) mobile only; (iii) and both fixed-line and mobile based on structural model derived from dis-

[2]In Slovenia, a survey conducted on behalf of APEK, the Slovenian regulatory authority, found that "34.6% of those interviewed had considered cancelling their fixed telephone connection because of the wide-spread use of mobile telephony. The majority of these were male, middle age, having a high school education, students and those with the highest income." Source: European Regulators Group (2009).

[3]According to Eurobarometer (2011), in March 2011, on average 71% of broadband access in the EU was by means of DSL but with significant differences across countries, especially between new and old Member States.

[4]Internet Protocol Television (IPTV) is a system through which television services are delivered using the Internet instead of traditional terrestrial, satellite signal and cable television.

crete choice framework. We find that decreasing prices for mobile services increase the share of 'mobile only' households and decrease the shares of 'fixed only' and 'fixed + mobile' households which suggests substitution between fixed-line and mobile connections. Moreover, growing Internet usage increased the share of 'fixed + mobile' households, which suggests that households keep their fixed line connection to access Internet. However, spread of 3G and cable modem broadband access decreases the share of 'fixed + mobile' households and increases the share of 'mobile only' households. Mobile broadband and cable modem are complements to mobile telephony, while DSL is complement to fixed-line telephony. Hence, deployment of alternative to DSL broadband technologies may further reduce fixed-line penetration. On the other hand, bundling increases the share of 'fixed + mobile' households and decreases the shares of 'mobile only' and 'fixed only' households, which suggests that operators which provide both fixed-line and mobile services may slow down the FMS by bundling these services.

The next section discusses related literature. Section 3 introduces the empirical framework. Section 4 presents the data. Section 5 discusses estimation results and finally Section 6 concludes.

2 Literature Review

There is a growing body of literature on substitution between fixed-line and mobile services, which was recently reviewed in Vogelsang (2010). Among country-level studies, Barros and Cadima (2000) estimate simultaneously diffusion curves for mobile and fixed telephony in Portugal and find a negative impact of mobile penetration on fixed-line density. Okada and Hatta (1999) use Almost Ideal Demand System (AIDS) and data on Japan to analyze demand for mobile and fixed-line telecommunications services. They find that own-price elasticities and substitution effect are relatively high. Rodini et al. (2003) estimate the substitutability of fixed-line and mobile access using data on U.S. households and binary logit model. They find that second fixed line and mobile services are substitutes for one another. In another paper, Ward and Woroch (2005) use the AIDS model for US household survey data and find significant positive cross-price elasticities between mobile and fixed-line usage. Grzybowski and Karamti

(2010) analyze the development of mobile telephony in France and Germany in 1998-2002 using binary logit model for aggregate data and conclude that consumers perceive mobile telephony as a substitute for fixed-line connection in France and as a complement in Germany. Briglauer et al. (2011) use monthly data on call minutes and price approximated by average revenues per minute in Austria between 2002 and 2007 to estimate short- and long-run cross-price elasticities for domestic calls on fixed-line with respect to mobile prices. They find that access is inelastic while calls are elastic and conclude that the retail market for national calls of private users can be deregulated due to sufficient competitive pressure from mobile. Access-substitution on the other hand does not seem to be strong enough to justify de-regulation.

Another range of studies analyzes the diffusion of mobile technology worldwide using cross-country panel data. For instance, Gruber and Verboven (2001) estimate a logistic diffusion model for mobile subscriptions in the EU. They find, among other results, that the penetration rate of fixed telephony has a negative influence on the diffusion of mobiles. However, studies for other countries suggest that mobile and fixed-line services may be complements: Gruber (2001) for Central and Eastern European countries; Gebreab (2002) for African countries; and Ahn and Lee (1999) for 64 countries worldwide. Hamilton (2003) finds that mobile and fixed-line subscriptions may be both complements and substitutes at different stages of market development based on data for African countries. In the early stage of diffusion, mobile services may be complement fixed-line telephones but the substitution effect takes over once mobile usage becomes more widespread.

In summary, the results of empirical studies are ambiguous with respect to whether mobile and fixed-line services are substitutes or complements. The contribution of this paper is to derive and estimate a structural model of household's demand for fixed-line only, mobile only and both fixed-line and mobile access in the EU countries. Such consumer decision framework was not considered so far in the previous literature due to lack of information on parallel usage of different telecommunications technologies by households. Estimating a structural demand model for aggregate data in which households choose between different technologies would not be possible without knowing the share of households using both mobile and fixed-line telephones. Such information has been published since a few years by the European Commission in the Eurobarometer reports.

3 Econometric Model

Demand equations are derived using discrete choice framework for aggregate data, in which we model decisions of households whether to use mobile and/or fixed-line telecommunications technologies. There are four types of households with respect to the usage of telecommunications services: (i) fixed-line only; (ii) mobile only; (iii) both fixed-line and mobile; and (iv) without access to any telecommunications services.[5] Figure (1) show distribution of household types across the EU countries in March 2011. Since the last type of households has a positive share only in some of the new Member States we ignore it in the further modeling.[6]

Household's decisions to subscribe to mobile, fixed-line and Internet are increasingly interrelated and the econometric modelling of them requires some simplifications. Typical empirical studies on diffusion of telecommunications technologies estimate a regression in which penetration of one technology is regressed on the penetration of other technologies. We derive consumer decision model of subscription to voice services, in which we assume that there are only two technologies available for voice calls: mobile or fixed-line telephony. Hence, we exclude VoIP as a potential substitute. Next, we assume that household's decision about which technology to use

[5]Another choice set specification may include "both fixed-line and mobile as a bundle" as additional choice alternative. There is however no such information available in the Eurobarometer reports. All we know is the share of households having a bundle but it is not clear what this bundle includes. Hence, we need to divide the households which declared using both mobile and fixed telephones into those who use these technologies as a bundle and unbundled. As long as the share of households using both mobile and fixed-line telephones is greater than the share of households with bundles, we can assume that the share of households without bundles is the difference between these two. The estimation results of such specification are not much different from our current estimates.

[6]In general, some households may not be interested in using neither mobile nor fixed-line even for a very low price level. Such households are inelastic and are not part of the market for access to telecommunications services.

for voice depends on penetration of Internet and on penetration of cable modem and 3G broadband. The reasoning behind this is that if there is higher Internet penetration, households may keep their fixed-line connection because it may be also used to access Internet via DSL. On the other hand, when penetration of cable modem and 3G is higher, which indicates a greater availability of these technologies, households may give up their fixed-line connection for both Internet and voice services. We assume that Internet, cable modem and 3G broadband penetration are exogenous, i.e., a shock which influences the share of households with mobile telephones only does not affect the penetration of broadband technologies. Also, a greater share of households using bundles indicates greater availability of such offers which may increase households' valuation of having both mobile and fixed-line at the same time.

The utility derived by household i from country j from using fixed-line telecommunications services in period t is given by:

$$U_{ifjt} = r_f - \alpha_f p_{fjt} + \gamma_f X_{jt} + \xi_{fjt} + \epsilon_{ifjt} = \delta_{fjt} + \epsilon_{ifjt}, \qquad (1)$$

where r_f is time-invariant stand alone value of fixed-line telephony; p_{fjt} is the price paid for using fixed-line services in period t; X_{jt} are country-specific factors affecting utility from fixed-line in period t; ξ_{fjt} is the mean unobserved utility of fixed-line telephony in period t, which is assumed to be iid normally distributed. Finally, ϵ_{ifjt} is an idiosyncratic taste variable which is assumed to be type I extreme value distributed. The mean utility level from using a fixed-line in period t is denoted by δ_{fjt}. The following variables included in the vector X_{jt}: income approximated by GDP per capita; availability of bundled offers approximated by the share of households using bundles; availability of 3G and cable modem broadband approximated by the share of households using these technologies; share of households having access to Internet; lagged number of mobiles per population which approximates network effects.[7] These variables

[7]The utility of using mobile telephones may be affected by network effects, i.e., the greater is the number of mobile phone users the greater is the range of communications possibilities and the greater is the valuation of mobile services versus fixed-line services. We assume that households form expectations about the number of mobile users in the subscription decision period which is equivalent to observed number of users in the previous period (see for instance Doganoglu and Grzybowski (2007)).

vary across countries and over time.[8]

The utility derived by household i from country g from using exclusively mobile telecommunications services in period t can be written analogously:

$$U_{imjt} = r_m - \alpha_m p_{mjt} + \gamma_m X_{jt} + \xi_{mjt} + \epsilon_{imjt} = \delta_{mjt} + \epsilon_{imjt}, \quad (2)$$

where r_m is time-invariant stand alone value of mobile telephony; p_{mjt} is the price paid for using mobile services in period t; X_{jt} are country-specific factors which affect utility from mobiles in period t and are assumed to be the same as in the case of fixed-line. The same distributional assumptions hold for the mean unobserved utility of mobile telephony in period t, ξ_{mjt}, and the idiosyncratic taste variable, ϵ_{imjt}. The mean utility level of using a mobile services in period t is denoted by δ_{mjt}.

When consumers decide to use mobile services together with fixed-line, the utility of both technologies may change, which is denoted by $\lambda_f \delta_{fjt}$ and $\lambda_m \delta_{mjt}$, where $\lambda_f \geq 0$ and $\lambda_m \geq 0$. Thus, the utility of using mobile services together with fixed-line in period t is given by:

$$\begin{aligned} U_{ibjt} &= \lambda_f \delta_{fjt} + \lambda_m \delta_{mjt} + \epsilon_{ibjt} \\ &= (\lambda_f r_f + \lambda_m r_m) - \lambda_f \alpha_f p_{fjt} - \lambda_m \alpha_m p_{mjt} + (\lambda_f \gamma_f + \lambda_m \gamma_m) X_{jt} + (\lambda_f \xi_{fjt} + \lambda_m \xi_{mjt}) + \epsilon_{ibjt} \\ &= \delta_{bjt} + \epsilon_{ibjt} \quad (3) \end{aligned}$$

where δ_{bjt} is the mean utility level of using fixed-line together with mobile services.

We normalize all utilities with respect to the utility of using both fixed-line and mobile services. After subtracting δ_{bjt}, equation (1) can be written as:

$$\begin{aligned} \bar{U}_{ifjt} &= [(1-\lambda_f) r_f - \lambda_m r_m] - (1-\lambda_f) \alpha_f p_{fjt} + \lambda_m \alpha_m p_{mjt} \\ &\quad + [(1-\lambda_f)\gamma_f - \lambda_m \gamma_m] X_{jt} + [(1-\lambda_f)\xi_{fjt} - \lambda_m \xi_{mjt}] + \epsilon_{ifjt} \\ &= \bar{\delta}_{fjt} + \epsilon_{ifjt}, \quad (4) \end{aligned}$$

[8] Typically, fixed-line and mobile penetration is regressed on income and regulatory variables, such as implementation of number portability, but since in the time period of our data regulatory measures were already implemented in almost all EU countries we do not include any regulatory variables in the regressions.

The coefficient for the price for mobile services should be non-negative since $\lambda_m \geq 0$ and $\alpha_m \geq 0$. The sign of the coefficient for the price for fixed-line services is ambiguous. The sign is negative when $\lambda_f < 1$, i.e., the utility of fixed-line connection decreases when the consumer acquires mobile telephone. Thus, mobile and fixed-line services are perceived as substitutes. The sign is positive when $\lambda_f > 1$, i.e., the utility of fixed-line services increases. In this case, mobile and fixed-line services are complements. Finally, the coefficient is insignificant when $\lambda_f = 1$, i.e., there is no change in the utility of fixed-line services when used together with mobile phones. Hence, mobile and fixed-line are neither complements nor substitutes.

Equation (2) after subtracting δ_{bjt} can be written as:

$$\begin{aligned}\bar{U}_{imjt} \quad &= [(1-\lambda_m)r_m - \lambda_f r_f] + \lambda_f \alpha_f p_{fjt} - (1-\lambda_m)\alpha_m p_{mjt} \\ &+[(1-\lambda_m)\gamma_m - \lambda_f \gamma_f]X_{jt} + [(1-\lambda_m)\xi_{mjt} - \lambda_f \xi_{fjt}] + \epsilon_{ifjt} \\ &= \bar{\delta}_{mjt} + \epsilon_{imjt}, \end{aligned} \tag{5}$$

In this equation, the coefficient for the price for fixed-line services should be non-negative because $\lambda_f \geq 0$ and $\alpha_f \geq 0$. The sign of the coefficient for the price for mobile services is ambiguous: (i) negative when $\lambda_m < 1$, i.e., mobile and fixed-line services are perceived as substitutes; (ii) positive when $\lambda_m > 1$, i.e., mobile and fixed-line services are complements and (iii) insignificant when $\lambda_m = 1$, i.e., there is no change in utility of mobile services when used together with fixed-line.

The probability that consumer i subscribes only to fixed-line services in period t may be written as:

$$\bar{P}_{ifjt} = \frac{\exp(\bar{\delta}_{fjt})}{1+\exp(\bar{\delta}_{fjt})+\exp(\bar{\delta}_{mjt})}, \tag{6}$$

and analogously for subscription to mobile services only. The demand equations can be derived using the transformation suggested in Berry (1994). The market size is represented by all households having access to fixed-line or mobile services. Denote by: $\bar{s}_{fjt}$ the share of 'fixed only' households in period t; $\bar{s}_{mjt}$ the share of 'mobile only' households; and $\bar{s}_{bjt} = 1 - \bar{s}_{mjt} - \bar{s}_{fjt}$

the share of 'fixed + mobile' households. Demand for fixed-line only can be written as:

$$\log(\bar{s}_{fjt}/\bar{s}_{bjt}) = \bar{r}_f - \bar{\alpha}_{ff}p_{fjt} + \bar{\alpha}_{fm}p_{mjt} + \bar{\gamma}_f X_{jt} + \bar{\xi}_{fjt}. \tag{7}$$

and demand for mobile only can be written as:

$$\log(\bar{s}_{mjt}/\bar{s}_{bjt}) = \bar{r}_m + \bar{\alpha}_{mf}p_{fjt} - \bar{\alpha}_{mm}p_{mjt} + \bar{\gamma}_m X_{jt} + \bar{\xi}_{mjt}. \tag{8}$$

The assumption on the idiosyncratic taste variable ϵ_{imjt} being uncorrelated across choice alternatives implies symmetric substitution patterns between choice alternatives (see Train (2003)). Since we have only three choice alternatives in the model we are not particularly worried about this issue. Multinomial logit should be sufficient to model consumer behaviour in our specific situation and to assess the extent of FMS. In fact, we cannot identify all the parameters in equations (4) and (5). In particular, we cannot identify the coefficients α_m and α_f which are needed to estimate price elasticities, so that we only comment on the significance and signs of particular estimates.

By construction, the contemporaneous correlation of the error terms in these equations is non-zero, $E(\bar{\xi}_{fjt}\bar{\xi}_{mjt}) \neq 0$, but since each equation contains exactly the same set of regressors, a joint estimation of both equations is as efficient as a separate equation-by-equation estimation which is our approach (see Amemiya (1985)).

Estimation Strategy The demands for fixed-line and mobile access (7) and (8) are regressed on prices for mobile services, which may be endogenous and require instrumental variables (IV) estimation method. The other explanatory variables used in the model are considered to be exogenous and may be used as instruments. In particular, price indices for fixed-line services are assumed to be exogenous because fixed-line markets in the EU countries were liberalized between 1993 and 2001. There have been many market entries and increasing level of competition, especially in the markets for national and international calls. Retail prices for fixed-line are also regulated in some of the EU countries (see Grzybowski (2008)).

To fulfil the condition for identification we have to find at least one variable which is correlated with price but is not correlated with demand. Cost factors are commonly used in the empirical literature as instruments for prices but we lack reliable data on costs. Instead, we can use mobile telecommunications prices in other markets as instruments for prices in a given market, as suggested in Hausman (1996) and Nevo (2001). Mobile network operators across Europe use similar technologies to provide services, which are produced by a small number of corporations. Also, the cost of capital is correlated across selected EU countries. In result, prices in different countries should be correlated due to common cost determinants. We use as instrument for mobile prices in one country mobile prices in selected neighbouring country, with the highest correlation. For instance, mobile prices in Belgium are instrumented with mobile prices in Luxembourg; and mobile prices in Czech Republic are instrumented with mobile prices in Hungary. The condition for these prices to be valid instruments is that the shocks which influence the share of households using mobile or fixed-line in these countries are not correlated. For instance, marketing actions and periods of intense competition between mobile operators are certainly not correlated across countries because telecommunications markets have national character. Similarly, implementation of any regulatory measures is not fully coordinated across countries. On the other hand, economic growth may be correlated across countries but we control for it using GDP per capita in the regressions.

Apart from prices in other countries we can also use as an instrument lagged prices in the same country, which are highly correlated with the contemporaneous prices and at the same time not affected by contemporaneous shocks to demand. The validity of this instrument hinges upon the assumption that there is no autocorrelation of the error term.

In the final regressions, we use two variables as instruments: lagged price for mobile services in the same country and contemporaneous price for mobile services in selected neighbouring country, for which there is the highest correlation with the instrumented price. We test the validity of instruments using Sargan test for overidentifying restrictions. For all the IV regressions discussed in the next section we cannot reject the null hypothesis that the instruments are uncorrelated with the error terms, i.e., the instruments are valid.

4 The Data

The data used in this paper was collected from the following sources, as shown in Table (1).

Technology shares: The data on different types of telephone and Internet access at home in 27 Member States of the European Union comes from the "Eurobarometer: E-Communications Household Surveys" carried out by TNS Opinion & Social Network on behalf of the European Commission. The purpose of these surveys is to follow trends in electronic communications markets and to assess how EU households and citizens derive benefits from increasingly competitive and innovative digital environment. So far there were five Eurobarometer surveys which were conducted in: December 2005 – January 2006; November-December 2006; November 2007 – January 2008; November-December 2009 and February-March 2011. In the most recent survey, the interviews were conducted among 26,836 households in 27 EU countries. In this paper we use aggregate response data on household level which is publicly available in reports published on the websites of the European Commission.[9]

Prices: Data on prices of mobile and fixed-line telecommunications services comes from the reports on "Telecoms Price Developments" produced on regular basis by consultancy firm Teligen on behalf of the European Commission's Directorate General for Information Society. The objective of these reports is to analyze price developments in the Member States of the European Union in years 1998-2010. The reports show prices as of 1st August each year from 1998 to 2004, as of 1st September from 2005 to 2007, and as of 15th September from 2008 to 2010. Teligen collected tariff data directly from the telecoms operators, from their websites and price-lists. Data were validated by the NRAs to reinforce the reliability of the information.[10]

[9] A technical note on the way in which the interviews were conducted by the institutes within the TNS Opinion & Social Network can be found in the annex to these reports.

[10] We have to match Teligen's pricing data with Eurobarometer data. Teligen data for years 2005-2010 was collected in September, which is a few months earlier than Eurobarometer data collected usually towards the end of the year. We assume that Eurobarometer data with fieldwork in: December 2005 – January 2006 relates to 2005 Teligen data; November-December 2006 relates to 2006; November 2007 – January 2008 relates to 2007;

Prices used in this study are so called ‘composite baskets’ which are constructed by calculating the cost of a fixed number of different calls per annum, including annual rental charge as well as installation charge depreciated over five years. The number and distribution of calls are kept constant throughout the whole period. For fixed-line services, Teligen uses tariff data for the incumbent operator in each country. Standard tariffs are used excluding any special prices. Hence, the cost of the tariff is not necessarily the lowest on the market. Mobile prices are constructed using mobile tariffs selected by Teligen for the “OECD Price Benchmarking Baskets”. Prices are calculated using representative tariffs from two network operators with the greatest number of subscribers. In the regression we use an average of these two prices for each country.[11]

The key inputs into demand models specified by equations (7) and (8) are shares of households using different telecommunications technologies and prices for fixed-line and mobile services. Figures (2) and (3) show dependencies between the ratio of mobile to fixed-line prices and the percentage of ‘fixed only’ and ‘mobile only’ households, respectively. There is a negative correlation between the ratio of mobile to fixed-line prices and the share of ‘mobile only’ households, i.e., the more expensive is fixed-line the greater is the share of ‘mobile only’ households and the more expensive are mobiles the smaller is the share. Similarly, there is a negative correlation between the ratio of fixed-line to mobile prices and fixed-line penetration, i.e., the more expensive is fixed-line the lower is the share of ‘fixed only’ households and the more expensive are mobiles the higher is the share of ‘fixed only’ households. Figures (4) and (5) show dependencies between the share of households with both fixed-line and mobile access and the percentage of households using Internet and cable broadband, respectively. These figures indicate that the percentage of ‘fixed + mobile’ households is positively correlated with the share of households using Internet. On the other hand, share of households using Internet through cable

November-December 2009 relates to 2009 and February-March 2011 relates to 2010. We miss Eurobarometer data for year 2008 because the survey was not conducted in this year.

[11]The definitions of the fixed-line and mobile ‘composite baskets’ are explained in detail in Teligen’s reports, which are publicly available on the website of the European Commission.

modem is negatively correlated with percentage of households with both fixed-line and mobile access. Thus, the means of Internet access may be among the factors which impact the degree of fixed-to-mobile substitution.

Table (1) shows summary statistics for variables used in the regressions. Except for mobile prices, which are missing for two years for Bulgaria and Romania, there are five years of data for 27 EU countries totalling 135 observations. The data covers years 2005-2010, except year 2008 in which Eurobarometer survey was not conducted. Table (2) shows correlation analysis using cross-country time series data. The correlations of the shares of 'fixed-line only' and 'mobile only' households with the other variables are plausible. In particular, the share of 'fixed-line only' households is negatively correlated with fixed-line price and positively correlated with mobile price. The share of 'mobile only' households is negatively correlated with mobile price and positively with fixed-line price. It is also positively correlated with the shares of households using 3G and cable modem to access Internet and negatively correlated with the share of households using bundles.

5 Estimation Results

Multinomial logit: Tables (3) and (5) present estimation results for equation (7) and (8), respectively. First, we estimate these equations using OLS, followed by random effects and fixed effects regressions. The country-specific effects control for all time-invariant differences between countries and they absorb the impact of variables used in the model which do not vary significantly over time. Hence, such variables become insignificant when country-specific effects are estimated. Fixed effects regression allows for the country-specific effects to be correlated with the independent variables. Random effects regression, on the other hand, takes into account presence of country-specific effects which are assumed to be uncorrelated with the independent variables. If the random effects assumption holds, the random effects model is more efficient than the fixed effects model. However, if this assumption does not hold, the random effects model is not consistent. Finally, we estimate random and fixed effects instrumental variables

(IV) regressions to take into account potential endogeneity of prices for mobile services, which we discussed in the previous section. To decide between fixed and random effects we use Hausman test, in which the null hypothesis is that the unique errors are not correlated with the regressors, i.e., the preferred model is random effects.

In the case of demand for fixed-line only services given by equation (7), the Hausman test with statistics $\chi^2 = 9.17$ does not allow to reject the null hypothesis that random effects are not correlated with the regressors with significance level of 0.33. Hence, random effects model (Model V in Table (3)) is preferred to fixed effects model (Model IV) as more efficient. Model V shows that prices for fixed-line and mobiles are insignificant. Given our specification of demand, insignificant prices can be interpreted as $\lambda_f = 1$ and $\lambda_m = 0$. The first equality implies that there is no change in the utility of fixed-line services when used together with mobile phones. The second equality means that the utility of mobile service is zero when used together with fixed-line. The first effect may be due to the fact that fixed-line is used to access Internet and hence its utility does not change when used with mobile telephones. The second effect is not intuitive.

The only variables which are significant in the random effects IV regressions are the share of households using bundled offers and Internet penetration. Bundled offers may reduce demand for having fixed-line connection only, i.e., there is more demand for having fixed-line and mobile connections together. The spread of Internet usage decreases demand for having fixed-line connection only. Since spread of Internet has no effect on the share of 'mobile only' households in the estimation of equation (8), households which use mobiles do not give up fixed-line connection to be able to access Internet. Usage of mobile broadband and cable modem has no effect on the demand for fixed-line only.

In the case of demand for mobiles only connection given by equation (8), the Hausman test with statistics $\chi^2 = 10.81$ also does not allow to reject the null hypothesis that random effects are not correlated with the regressors with significance level of 0.21. Hence, random effects model (Model V in Table (4)) is preferred to fixed effects model (Model IV) as more efficient.

In Model V, prices for mobile services have a significant and negative impact on the demand for using mobile phones only, relative to having fixed-line and mobile connections together. Prices for fixed-line services are insignificant which, given our specification of demand, can be interpreted as $\lambda_f = 0$. This implies that the utility of fixed-line service is zero when used together with mobiles, which contradicts our conclusion from the estimation of equation (7), where we concluded that $\lambda_f = 1$. Another possibility is that we are not be able to identify the effect of fixed-line prices due to data issues. We verify the price effects without imposing any structure on the data by estimating simple linear regressions discussed below, in which fixed-line prices are never significant.

There is also a negative effect of the share of households using bundles on the demand for having mobile phones only. This result is analogous to the regression of demand for fixed-line only shown in Table (3), i.e., bundle offers encourage households to use both technologies at the same time. Moreover, the share of households using mobile broadband has a positive impact on the demand for having mobile connection only. This suggests that the share of 'mobile only' households should increase with increasing usage of mobile broadband. Also, cable modem penetration increases the demand for using mobile phones only. Mobile broadband and cable modem penetration account for the availability of alternative means of Internet access to copper-based DSL. Hence, usage of mobile broadband and cable modem for data services is complementary to usage of mobile services for voice. On the other hand, according to results in Table (3) the share of 'fixed only' households decreases when Internet penetration increases. Hence, Internet access via DSL is complementary to usage of fixed-line phones for voice. The lagged number of mobile subscribers per population is significant and positive which suggests that the utility of using mobile phones increases with a greater number of mobile users. This effect is measured relative to using both fixed-line and mobile phones and can be expected to cancel out. It is insignificant in the estimation of demand for fixed-line only services given by equation (7).

Linear regression analysis: In addition to estimating structural demand for fixed-line only and mobile only connections given by equations (7) and (8), we also estimate linear regressions in which shares of 'fixed only', 'mobile only' and 'fixed+mobile' households are regressed on the same set of explanatory variables. These regressions are similar to typical studies on technology penetration based on aggregate data, and their purpose is to compare the structural approach with non-structural.

Estimation results for linear fixed and random effects IV regressions are presented in Table (5). In the regression of the share of 'fixed only' households, the Hausman test with statistics $\chi^2 = 29.10$ allows to reject the null hypothesis that random effects are not correlated with the regressors. Hence, fixed effects model (Model I) is preferred to random effects model (Model II). There is a negative impact of Internet penetration on the share of 'fixed only' households which is analogous to the logit estimation. However, the share of households using bundled offers is not significant. Also, the share of 'fixed only' households is not influenced by penetration of mobile broadband and cable modem, as in the logit regression.

In the regression of the share of 'mobile only' households, the Hausman test with statistics $\chi^2 = 3.42$ does not allow to reject the null hypothesis that random effects are not correlated with the regressors with significance level of 0.91. Hence, random effects model (Model IV) is preferred to fixed effects model (Model III). The results are analogous to the logit regression, except that Internet penetration is not significant. There is a negative impact of price for mobile services on the share of 'mobile only' households. Moreover, the share of households using bundles has a negative impact on the share of 'mobile only' households and the spread of mobile broadband and cable modem have a positive impact on the share of 'mobile only' households. The lagged mobile penetration has a positive impact on the share of 'mobile only' households. These results are analogous to the logit regression.

We also estimate a linear regression of the share of 'fixed + mobile' households on the same set of explanatory variables, as shown in Table (5). According to Hausman test with statistics $\chi^2 = 50.79$ the null hypothesis that random effects are not correlated with the regressors can be rejected. Hence, fixed effects model (Model V) is preferred to random effects model (Model VI). Model V in Table (5) shows that there is a positive impact of price for mobile services on the share of 'fixed + mobile' households. This suggests that households may be less likely to give up on fixed-line connection when mobile prices are high. Share of households using bundled offers is positively correlated with the share of households using both fixed-line and mobile connections. Spread of Internet positively influences share of 'fixed + mobile' households. On the other hand, share of households using mobile broadband and cable modem has a negative impact on the share of households having both fixed-line and mobile. The lagged penetration of mobiles also has a negative effect on the share of 'fixed + mobile' households. These results support the results of regressions based on discrete choice framework discussed above.

6 Conclusion

Over the past few years, the incumbent operators in most EU countries have seen a decline in its fixed-line business as consumers have increasingly used mobile phones to communicate. At the same time there is a large variation within the EU in the extent to which households use fixed-line only, mobile only or both technologies. In this paper we analyze substitutability between fixed-line and mobile telephony in 27 EU countries in years 2005-2010 using cross-country panel data on households' choices of telecommunications technologies. We derive a structural model of household's demand for fixed-line only, mobile only and both fixed-line and mobile access. We find that decreasing prices for mobile services increase the share of mobile only households and decrease shares of fixed only and fixed + mobile households which suggests substitution between fixed-line and mobile connections.

We also find that growing Internet usage increases the share of 'fixed + mobile' households, which suggests that households increasingly keep their fixed-line connection to access Internet. However, spread of cable modem and 3G broadband access decreases the share of 'fixed + mobile' households and increases the share of 'mobile only' households. On the other hand, bundling increases the share of 'fixed + mobile' households and decreases the shares of 'mobile only' and 'fixed only' households. We conclude that the spread of Internet is a factor which postpones fixed-to-mobile substitution. However, the usage of mobile broadband and cable modem reinforce the transition towards 'mobile only' or 'mobile + cable modem' households. These results indicate that future penetration of fixed-line will depend on the development of alternative means of Internet access. When the quality and speed of mobile broadband increases the number of fixed-line connections may be expected to decline. Firms may postpone this decline by promoting bundled offers of mobile and fixed-line services.

Due to lack of detailed data on the share of households using mobile and fixed-line connections together, all previous studies analyzing fixed-to-mobile substitution used data on the numbers of mobile and fixed-line connections. This paper improves upon it by using results from the Eurobarometer surveys, which provide information on the usage of different telecommunications technologies. The contribution of this paper is to derive and estimate a structural model of household's demand for fixed-line only, mobile only and both fixed-line and mobile access in the European Union. Our results provide useful information for the policy makers. We suggest that there is ongoing fixed-to-mobile substitution which is slowed down by spread of Internet but it is likely to continue with the deployment of alternative to DSL broadband technologies such as mobile broadband and cable modem.

References

Ahn, H. and M.H. Lee, 1999. "An Econometric Analysis of the Demand for Access to Mobile Telephone Networks," *Information Economics and Policy*, 11, pp.297-305.

Amemiya, T., 1985. "Advanced Econometrics," *Harvard University Press.*

Barros, P. and N. Cadima, 2000. "The impact of mobile phone diffusion on the fixed-link network," *CEPR Discussion Paper*, No.2598.

Berry, S.T., 1994. "Estimating Discrete-Choice Models of Product Differentiation," *RAND Journal of Economics*, 25(2), pp.242-262.

Briglauer, W., Schwarz, A. and C. Zulehner, 2011. "Is fixed-to-mobile substitution strong enough to deregulate fixed voice telephony? Evidence from the Austrian markets," *Journal of Regulatory Economics*, 39, pp.50-67.

Doganoglu, T. and L. Grzybowski, 2007. "Estimating network effects in the mobile telecommunications industry in Germany," *Information Economics and Policy*, 19(1), pp.65-79,

European Regulators Group (2009), "Report on fixed-mobile convergence: implications on competition and regulatory aspects", ERG (09)06.

Eurobarometer, 2006. "E-Communications Household Survey: Fieldwork December 2005 – January 2006," available at http://ec.europa.eu/public_opinion/inde_en.htm.

Eurobarometer, 2011. "E-Communications Household Survey: Fieldwork February-March 2011," available at http://ec.europa.eu/public_opinion/inde_en.htm.

Gebreab, F.A., 2002. "Getting Connected: Competition and Diffusion in African Mobile Telecommunications Markets," World Bank Policy Research Working Paper 2863.

Gruber H. and F. Verboven, 2001. "The Diffusion of Mobile Telecommunication Services in the European Union," *European Economic Review*, 45, pp.577-588.

Gruber, H., 2001. "Competition and Innovation: The Diffusion of Mobile Telecommunications in Central and Eastern Europe," *Information Economics and Policy*, 13(1), pp.19-34.

Grzybowski, L., and Ch. Karamti, 2010. "Competition in mobile telephony in France and Germany," *Manchester School*, 78(6), pp.702-724.

Grzybowski, L., 2008. "The impact of regulation on the retail prices in fixed-line telephony across the European Union," *Telecommunications Policy*, 32(2), pp.131-144.

Hamilton J., 2003. "Are main lines and cell phones substitutes or complements? Evidence. from Africa," *Telecommunications Policy*, 27, pp.109-133.

Hausman, J. 1999. "Cellular Telephone, New Products, and the CPI." *Journal of Business and Statistics*, 27(2).

Lee, Y-H. and N. Sung, 2002. "Substitution between Mobile and Fixed Telephones in Korea," *Review of Industrial Organization*, 20(4), pp.367-374.

Okada, Y. and K. Hatta, 1999. "The Interdependent Telecommunications Demand and Efficient Price Structure," *Journal of the Japanese and International Economies*, 13(4), pp.311-335.

Rodini, M., Ward M. and G. Woroch, 2003. "Going Mobile: Substitution Between Fixed and Mobile Access," *Telecommunications Policy*, 27, pp.457-476.

Train, K., 2003. "Discrete Choice Methods with Simulation," *Cambridge University Press*, Cambridge.

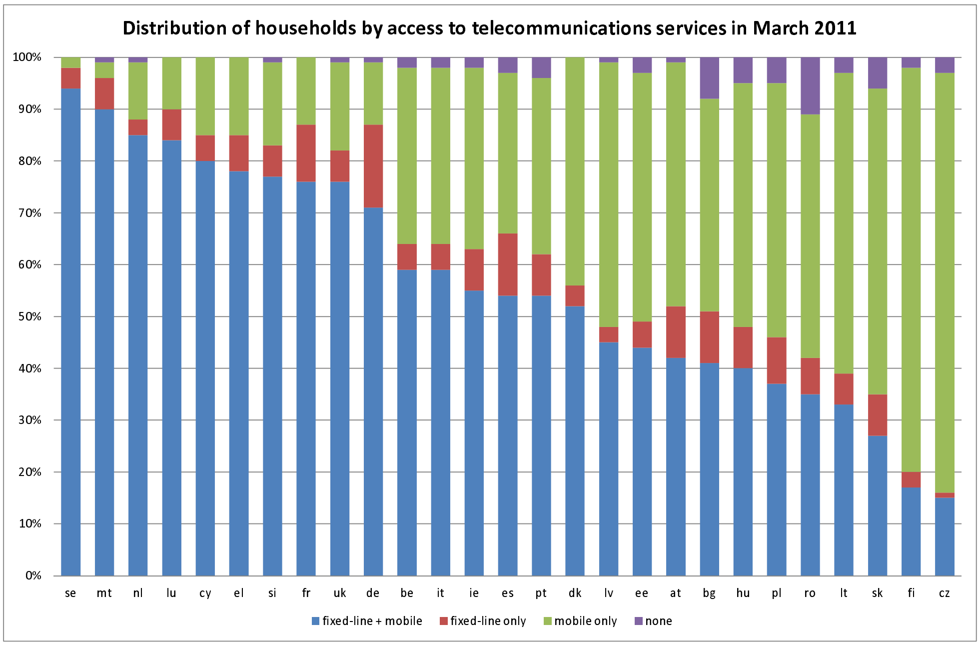
Ward, M.R. and G.A. Woroch, 2005. "Fixed-Mobile Telephone Subscription Substitution in the U.S," Working Papers 0501, University of Texas at Arlington, Department of Economics.

Ward, M.R. and S. Zheng, 2012. "Mobile and fixed substitution for telephone service in China," *Telecommunications Policy*, 36(4), pp.301-310.

Vogelsang, I., 2010. "The relationship between mobile and fixed-line communications: A survey," *Information Economics and Policy*, 22(1), pp.4-17.

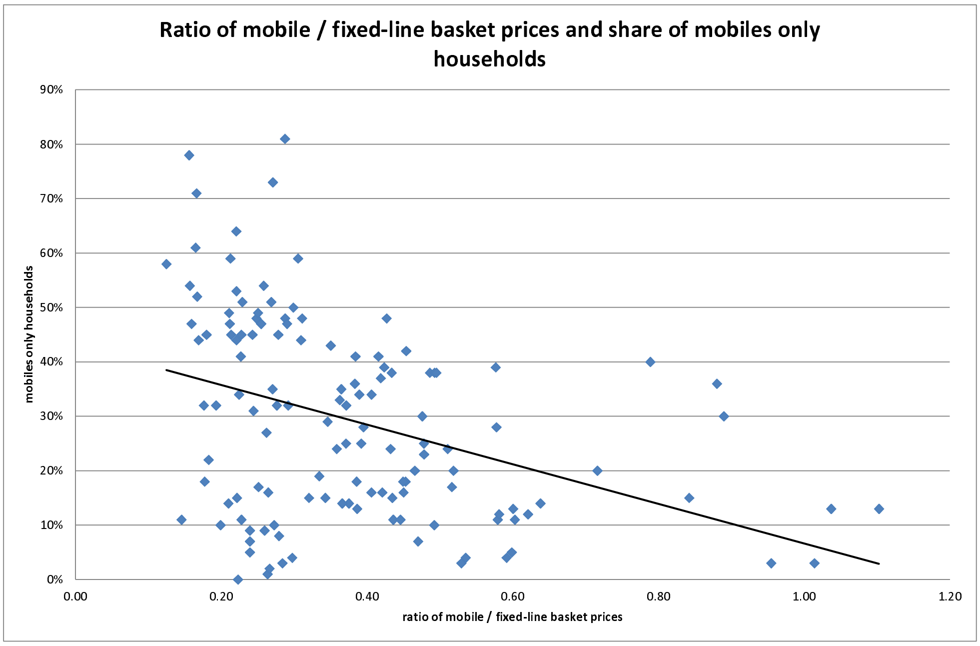
Appendix

Figure 1:



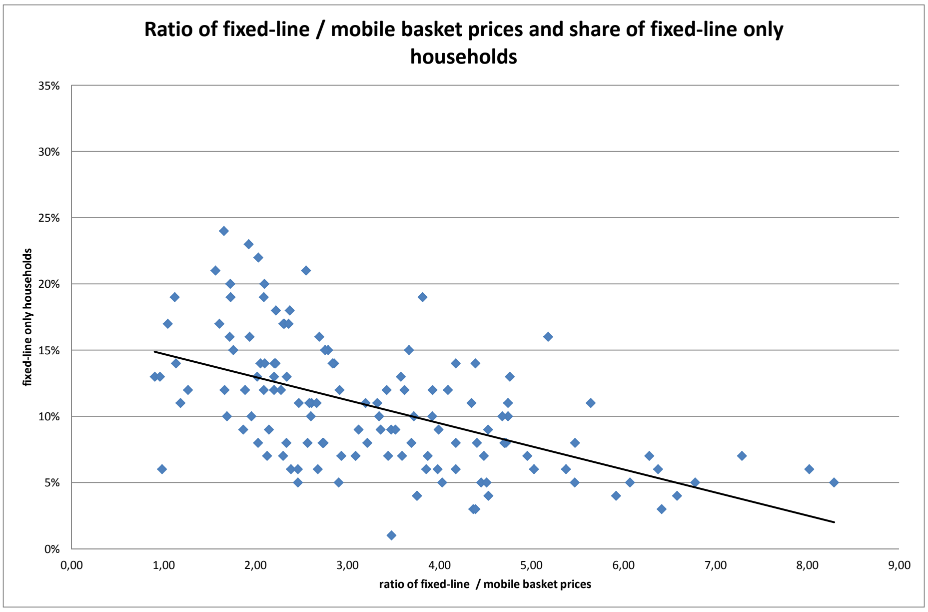
Source: "Eurobarometer: E-Communications Household Surveys", 2011: fieldwork in February-March 2011

Figure 2:



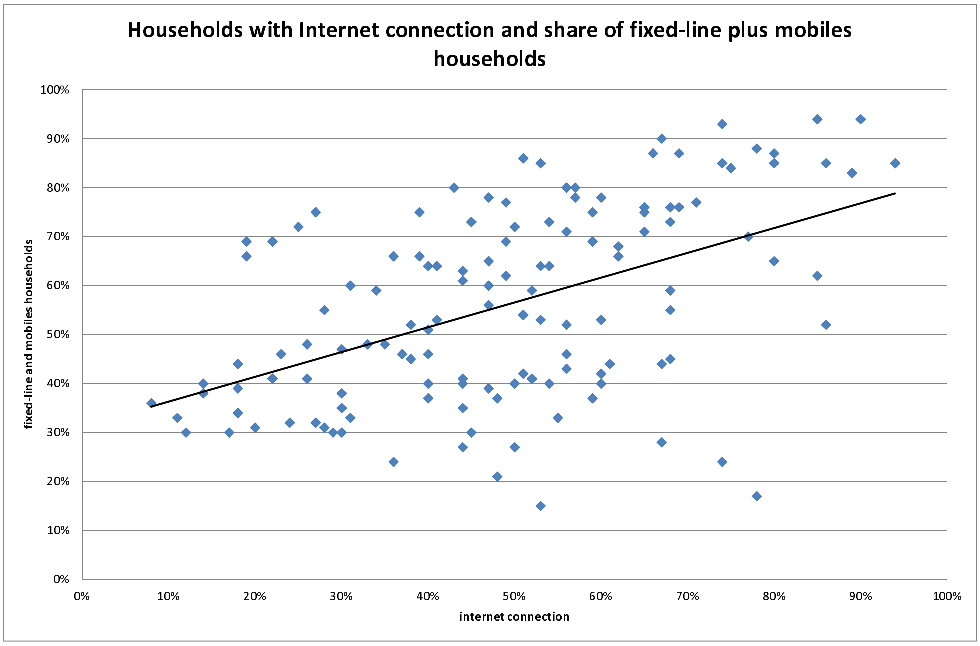
Source: Eurobarometer and Teligen, 2005-2010. Each data point represents country-year observation (131 observations).

Figure 3:



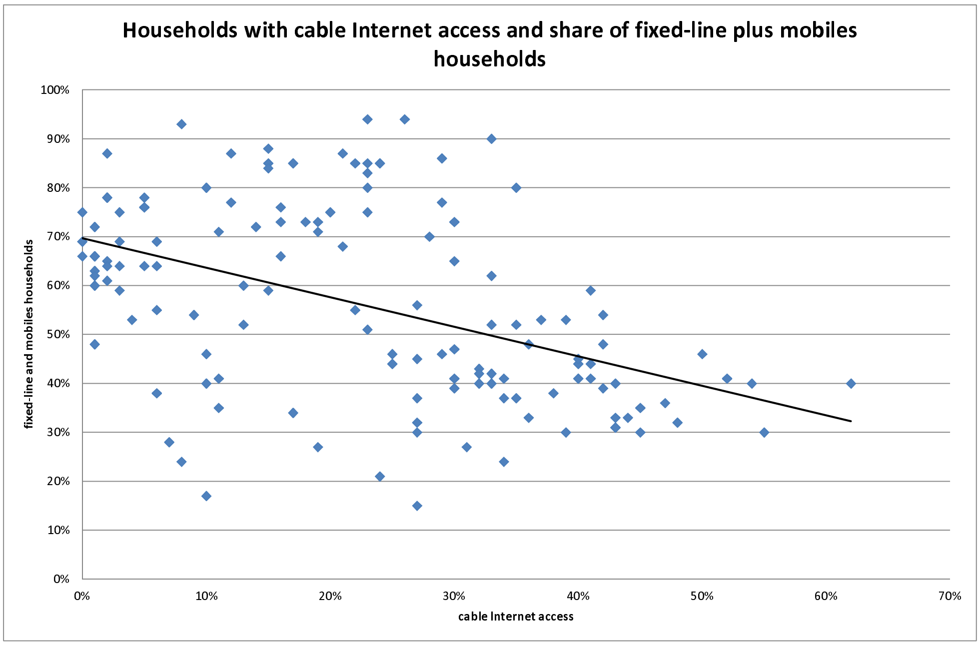
Source: Eurobarometer and Teligen, 2005-2010. Each data point represents country-year observation (131 observations).

Figure 4:



Source: Eurobarometer, 2005-2011. Each data point represents country-year observation (135 observations).

Figure 5:



Source: Eurobarometer, 2005-2011. Each data point represents country-year observation (135 observations).

Table 1: Summary statistics

variable	N	mean	std	min	max	Source
Fixed only (%)	135	0.11	0.05	0.01	0.31	Eurobarometer
Mobile only (%)	135	0.29	0.18	0.00	0.81	Eurobarometer
Fixed+Mobile (%)	135	0.56	0.20	0.15	0.94	Eurobarometer
Price mobile (Euros)	131	13.28	6.22	4.17	31.95	Teligen
Price fixed (Euros)	135	36.32	7.70	16.27	57.42	Teligen
GDP PPP per capita (tsd Euros)	135	23.34	10.66	7.90	69.10	Eurobarometer
Bundles (%)	135	0.28	0.14	0.00	0.67	Eurobarometer
3G penetration (%)	135	0.04	0.05	0.00	0.29	Eurobarometer
Cable penetration (%)	135	0.23	0.15	0.00	0.62	Eurobarometer
Internet penetration (%)	135	0.49	0.19	0.08	0.94	Eurostat
Lagged mobiles (%)	135	1.08	0.23	0.47	1.80	Eurobarometer

The summary statistics is calculated for 27 EU countries for years 2005-2010 but excluding year 2008, for which Eurobarometer data is not available. There are also missing price observations for Bulgaria and Romania for years 2005-2006.

Table 2: Correlation analysis

	Fixed	Mobile	Fix+Mob	Price m	Price f	GDP	Bundle	3G	Cable	Internet	Lagged m
Fixed only (%)	1.00										
Mobile only (%)	-0.34	1.00									
Fixed+Mobile (%)	0.03	-0.94	1.00								
Price mobile (Euros)	0.51	-0.34	0.21	1.00							
Price fixed (Euros)	-0.09	0.16	-0.09	0.16	1.00						
GDP PPP per capita (tsd Euros)	-0.12	-0.42	0.52	-0.02	0.20	1.00					
Bundles (%)	-0.34	-0.21	0.33	-0.29	-0.08	0.25	1.00				
3G penetration (%)	-0.48	0.21	-0.04	-0.27	0.13	0.16	0.36	1.00			
Cable penetration (%)	-0.16	0.41	-0.44	-0.27	-0.22	-0.44	0.22	0.09	1.00		
Internet penetration (%)	-0.55	-0.24	0.47	-0.30	0.13	0.50	0.63	0.50	-0.04	1.00	
Lagged mobiles (%)	-0.49	0.13	0.04	-0.35	-0.03	0.31	0.28	0.32	-0.11	0.29	1.00

The correlations are calculated for cross country time series data.

Table 3: Logit demand for 'fixed only' connection

	Mod. I		Mod. II		Mod. III		Mod. IV		Mod. V	
	OLS	t-stat	FE	t-stat	RE	t-stat	FE IV	t-stat	RE IV	t-stat
Price mobile	-0.001	-0.15	0.002	0.45	0.001	0.12	-0.005	-0.57	-0.001	-0.07
Price fixed	0.003	0.65	-0.001	-0.19	-0.003	-0.63	-0.005	-0.99	-0.002	-0.36
GDP	0.006	1.44	0.000	0.07	-0.011	-0.81	-0.014	-0.98	0.000	0.03
Bundles	-0.185	-0.51	-0.518	-2.06	-0.548	-2.08	-0.575	-2.15	-0.536	-2.11
3G	0.532	0.54	0.474	0.86	0.705	1.23	0.809	1.38	0.520	0.93
Cable modem	0.713	2.62	0.412	1.20	0.447	0.99	0.341	0.72	0.307	0.85
Internet	-2.300	-9.92	-2.471	-7.47	-2.936	-6.75	-3.019	-6.48	-2.481	-7.18
Lagged mobiles	-0.577	-3.45	-0.048	-0.28	0.257	1.18	0.273	1.23	-0.049	-0.27
Intercept	-0.282	-0.90	-0.398	-1.28	-0.123	-0.27	0.143	0.27	-0.295	-0.83
R 2	0.64									
Hausman chi2									9.17	0.33
Sargan chi2									3.33	0.19

Model I: OLS; Model II: fixed effects; Model III: random effects; Model IV: fixed effects instrumental variables; Model V: random effects instrumental variables.

Table 4: Logit demand for 'mobile only' connection

	Mod. I		Mod. II		Mod. III		Mod. IV		Mod. V	
	OLS	t-stat	FE	t-stat	RE	t-stat	FE IV	t-stat	RE IV	t-stat
Price mobile	-0.060	-4.18	-0.024	-2.96	-0.018	-2.25	-0.028	-2.34	-0.045	-3.72
Price fixed	0.053	5.42	0.002	0.28	0.002	0.35	0.002	0.25	0.001	0.13
GDP	-0.025	-3.75	-0.006	-0.43	0.037	1.88	0.035	1.74	-0.004	-0.33
Bundles	-1.200	-1.38	-0.981	-2.54	-0.969	-2.62	-0.972	-2.58	-1.010	-2.53
3G	4.116	1.70	2.920	3.42	2.629	3.22	2.763	3.30	3.159	3.58
Cable modem	2.324	4.69	2.227	3.79	1.728	2.70	1.931	2.87	2.333	3.71
Internet	-2.861	-3.88	-1.277	-2.22	-0.733	-1.18	-1.025	-1.55	-1.702	-2.77
Lagged mobiles	0.922	2.85	0.923	3.17	0.686	2.24	0.634	2.02	0.782	2.55
Intercept	-1.287	-2.13	-1.178	-2.16	-2.166	-3.37	-1.820	-2.44	-0.556	-0.89
R 2	0.57									
Hausman chi2									10.81	0.21
Sargan chi2									0.80	0.37

Model I: OLS; Model II: fixed effects; Model III: random effects; Model IV: fixed effects instrumental variables; Model V: random effects instrumental variables.

Table 5: Share of 'fixed only', 'mobile only' and 'fixed + mobile' regressions

	Fixed				Mobile				Fixed+Mobile			
	Mod. I		Mod. II		Mod. III		Mod. IV		Mod. V		Mod. VI	
	FE IV	t-stat	RE IV	t-stat	FE IV	t-stat	RE IV	t-stat	FE IV	t-stat	RE IV	t-stat
Price mobile	0,001	1,530	0,002	3,220	-0,004	-2,370	-0,007	-3,870	0,004	1,83	0,006	3,19
Price fixed	0,000	-1,040	0,000	-0,230	0,000	-0,350	0,000	-0,310	0,000	0,38	0,000	0,40
GDP	-0,004	-3,260	0,000	-0,410	0,004	1,180	-0,002	-0,980	-0,005	-1,50	0,001	0,57
Bundles	0,001	0,070	0,007	0,320	-0,279	-4,770	-0,288	-4,650	0,258	4,10	0,266	4,11
3G	0,006	0,140	-0,034	-0,750	0,523	4,090	0,615	4,540	-0,532	-3,88	-0,599	-4,25
Cable modem	-0,046	-1,280	-0,071	-2,280	0,353	3,410	0,410	4,290	-0,348	-3,14	-0,421	-4,25
Internet	-0,224	-6,330	-0,161	-5,410	0,109	1,070	-0,020	-0,220	0,271	2,49	0,361	3,76
Lagged mobiles	0,002	0,120	-0,025	-1,640	0,091	1,860	0,120	2,560	-0,098	-1,89	-0,112	-2,29
Intercept	0,312	7,740	0,212	6,950	0,108	0,930	0,296	3,100	0,616	4,99	0,420	4,28
Hausman chi2			29,10	0,01			3,42	0,91			50,79	0,01
Sargan			0,23	0,63			0,78	0,67			1,17	0,28

Model I: fixed penetration IV fixed effects; Model II: fixed penetration IV random effects; Model III: mobile penetration IV fixed effects; Model IV: mobile penetration IV random effects; Model V: mobile+fixed penetration IV fixed effects; Model VI: mobile+fixed penetration IV random effects.