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Substitution and Complementarity between Fixed-line and Mobile Access

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Substitution and Complementarity between Fixed-line and Mobile Access ^{*}

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Abstract

We use rich survey data on 133,825 households from 27 EU countries during 2005-2011 to analyze substitution between fixed-line and mobile telecommunications services. We estimate a discrete choice model where households may choose between having mobile or fixed-line voice access only, or using both technologies at the same time. We obtain the following main findings. First, fixed-line and mobile connections are on average perceived as substitutes. But there is substantial heterogeneity across households and EU regions, with stronger substitution in Central and Eastern European countries. Second, there is strong complementarity between fixed-line and mobile connections that are offered by the fixed-line incumbent operator. This gives the incumbent a possibility to leverage its position in the fixed-line market into the mobile market. Third, fixed broadband technologies such as DSL and cable generate strong complementarities between fixed and mobile access, while mobile broadband strengthens substitution (at a smaller scale). The emergence of fixed broadband has thus been an important additional source through which incumbents leverage their strong position in the fixed-line network.

Keywords: fixed-to-mobile substitution; incumbency advantage; broadband access

JEL Classification: L13, L43, L96

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1 Introduction

At the start of the 1990s, telecommunications industries in the European Union were controlled by state monopolies which transmitted phone calls using copper lines infrastructure. There was a small number of mobile phone users via analog networks (1G), which in most of the EU countries were operated by the subsidiaries of the fixed-line incumbents. This situation changed drastically within the last two decades. In the early 1990s, competing mobile telecommunications operators started to deploy services based on second generation (2G) technologies GSM-900 and DCS-1800. In 1998, fixed-line telecommunications markets in the EU were liberalized and a large number of entrants started providing telecommunications services based on the fixed-line infrastructure of the incumbents. In late 1990s, the deployment of Internet broadband services started, which initially also mainly relied on existing copper networks.

With the deployment of these new technologies the number of communications options increased. This influenced the way in which people communicate with each other and consequently the use of copper-based fixed-line connections. The rapid increase in the number of mobile users was paralleled with a decline in the number of minutes that originated from fixed-line networks, and consequently also with a decline in the number of fixed-line subscribers. At the same time, the effect of broadband deployment on the usage of fixed-line connections is less obvious. Broadband Internet access was first deployed using digital subscriber line technology (DSL). This relied on copper-based networks and required consumers to maintain their fixed-line connections. In most of the EU countries, DSL is still a dominant broadband technology. But there are also countries, especially in Central and Eastern Europe (CEE), where alternative broadband technologies, such as cable, fibre and mobile broadband, obtained significant market shares.

A decline in the number of connections and deteriorating revenues may affect financial viability of the incumbent fixed-line operators. It is therefore critical for both the operators and industry regulators to understand the interdependencies between different communication technologies, so that these can be taken into account when regulating the industry. Since mobile

phones are now almost universally adopted, the substitution between fixed-line and mobile connections may be largely driven by the technology which households use to access the Internet. For instance, the substitution may increase with a decline in the number of DSL connections and increase with a rise in the number of mobile broadband connections. The question of fixed-to-mobile substitution is also important because of the ongoing consolidation process in telecommunications markets. There is a growing number of mergers between mobile operators which need to be scrutinized by the competition authorities, and substitution between fixed-line and mobile services should play an important role in the market investigations.

It is also interesting to what extent there are differences in the behaviour of consumers of telecommunications services across the EU countries and how they influence the transition from fixed-line to mobile telecommunications services. These differences may result from the historical development of telecommunications industry. But they may also be intrinsic to particular countries and result from different attitudes towards telecommunications technologies. The question is to what extent these differences should be taken into account when regulating telecommunications industry in the EU.

Another important question is how the convergence of fixed-line and mobile services influences competition and whether there is any incumbency advantage on the mobile market due to parallel ownership of fixed-line infrastructure and vice versa. In most of the EU countries, with the exception of United Kingdom, Romania and Lithuania, regulators granted mobile licences to fixed-line incumbents at the early stage of mobile market. Consequently, mobile operators which belong to the fixed-line incumbent are major players in the national markets. It is important to understand how this policy influenced development of fixed-line and mobile markets, and whether further consolidation of mobile and fixed-line markets is desirable from social welfare perspective.

There is a growing body of literature on substitution between fixed-line and mobile services, reviewed recently by Vogelsang (2010). Most of this literature uses cross-country or country-level aggregate data and finds substitution between fixed-line and mobile telecommunications services

(see for instance Gruber and Verboven (2001), Ward and Zheng (2012), Grzybowski (2013)). There is however no empirical study which analyzes differences in substitution between countries in a unified framework and takes household and country-specific idiosyncrasies into account.

Our paper contributes to the research on fixed-to-mobile substitution by making use of a unique micro-level dataset of 133,825 households from 27 EU countries during the period 2005-2011. We adapt the model of Gentzkow (2007) to model the situation in which households may choose bundles of different technologies: fixed voice or mobile voice only, or the combination of both services, with or without broadband Internet. We can summarize our results in three main findings.

Our first main finding is that households tend to perceive mobile and fixed-line connections as substitutes. But at the same time there is substantial heterogeneity across households and regions, so that both services are often perceived as complementary. In regions with a higher GDP per capita mobile and fixed-line services tend to be stronger substitutes. After controlling for GDP per capita, there is a stronger degree of substitution in the CEE countries, as compared to the WE countries. Apart from these two factors, there is still substantial heterogeneity across countries. Fixed-line and mobile services are strong substitutes in countries such as Romania, Finland, Lithuania or the Czech Republic. In contrast, they are weak complements in countries such as Sweden, the Netherlands and Malta. In the UK, Luxembourg and Slovenia, both technologies are independent from each other. There is not only heterogeneity in fixed-to-mobile substitution across regions, but also across households with different age, education, professional activity, etc. This implies that even within a region, individual households may perceive fixed-line and mobile connections as complements, despite the average substitutability of both voice services. Our finding that there is a lot of heterogeneity in the perceived substitutability between fixed-line and mobile voice services provides an explanation for the mixed results found in the previous literature that uses aggregate data.

Our second main finding relates to the role of the incumbents, i.e., the previous fixed-line monopolists, in the extent of fixed-to-mobile substitution. To investigate this, we extended the

model based on data for the years 2006 and 2007. For these years, we observe whether households have fixed voice and mobile voice at the incumbent or a competitor, enabling us to consider the simultaneous choice of fixed and mobile voice, at the incumbent or a competitor. We confirm that fixed-line and mobile connections are on average substitutes in these two years. Furthermore, we find that there is strong complementarity between fixed-line and mobile connections that are offered by the incumbent. Hence, although fixed-line incumbents do not have an advantage in the mobile market per se (often because they were second movers in the mobile market), they have an indirect advantage by offering both fixed and mobile services. This enables incumbents to leverage the strong position in the fixed-line market into the mobile market.

Our third main finding is that broadband Internet influences fixed-to-mobile substitution. To assess this, we extended the model further to consider the simultaneous choice of fixed versus mobile voice services and the choice of broadband technology (no broadband, dial-up, DSL, cable, mobile broadband and other). Also in this model specification we confirm that fixed-line and mobile connections are on average substitutes. In addition, we find that mobile broadband strengthens substitution between fixed-line and mobile connections. But more importantly, fixed broadband (through DSL, cable, etc) has been a strong force of complementarity between fixed-line and mobile connections. The emergence of fixed broadband has thus been an important additional source through which incumbents leverage their strong position in the fixed-line network. Although broadband Internet access is still not commonly adopted in many countries during our sample period, there is strong evidence that fixed Internet technologies have slowed down the substitution between fixed-line and mobile connections.

The remainder of the article is organized as follows. Section 2 discusses the relevant literature. Section 3 discusses the data used in the estimation. Section 4 introduces the econometric framework. Section 5 presents the estimation results. 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). Most of these studies use cross-country or country-level aggregate data and find substitution between fixed-line and mobile telecommunications services (see Gruber and Verboven (2001), Grzybowski and Karamti (2010), Ward and Zheng (2012), Grzybowski (2013)).

A number of other studies relies on consumer-level data. Rodini et al. (2003) estimate the substitutability between 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 (2010) use quarterly survey panel data in the U.S. for years 1999-2001 and a difference-in-difference analysis to estimate own- and cross-price elasticities of demand for fixed and mobile services and find moderate substitution between these two. García-Marinoso and Suarez (2013) use Spanish household panel data for the years 2004-2009 to analyze substitution from fixed to mobile services. They find that apart from household characteristics also the availability of Internet and mobile services plays a role, while prices and expenditures have no, or a small, impact on the substitution decision.

Among papers which focus on Internet access, Cardona et al. (2009) use household survey data for Austria to estimate discrete choice models and find that cable modem and mobile access are close substitutes to DSL and that they are in the same market as DSL. Srinuan et al. (2012) use discrete choice model on survey data for Sweden and find that mobile broadband and fixed broadband technologies are close substitutes when they are locally available. Grzybowski et al (2013) estimate a mixed logit model using survey data for Slovakia and find that mobile broadband should be included in the relevant market for Internet access based on fixed broadband technologies. None of these studies relate Internet access to the demand of fixed or mobile connections in voice services.

The studies mentioned above which use discrete choice framework essentially assume substitution between telecommunications technologies. There are only two recent studies, Liu et

al. (2010) and Macher et al. (2011), which explicitly model the possibility of substitution or complementarity between telecommunications technologies in a discrete choice framework. In the first paper, Liu et al. (2010) use a panel survey data of U.S. households for years 2004-2006 to estimate a discrete choice model for broadband services. Their model allows also for parallel choices of related services such as cable TV and local phone and for state-dependence in provider choices. They find evidence of strong complementarities between the consumption of broadband, cable TV and local phone services, where the main source of complementarities are the benefits derived by consumers from having a single provider for multiple services. In the second paper, Macher et al. (2012) estimate a consumer choice model using U.S. household data for years 2003-2010 to analyze whether fixed-line and mobile connections are substitutes or complements based on the model developed by Gentzkow (2007). They adapt the model to a situation in which households choose between having either mobile or fixed-line access and in addition allow for the use of both technologies at the same time. They find that connections to mobile and fixed-line telephony are substitutes rather than complements.

Since we also follow Gentzkow (2007), our base model is similar to Macher et al. (2012). But we also consider heterogeneity in substitution across households and across the many regions within the set of 27 EU countries. This allow us to conclude whether fixed-line and mobile connections are substitutes, complements or independent from each other in a particular country. We then comment on the hypothesis that consumers across the EU differ in the perception of fixed-line and mobile services and to what extent this is driven by population characteristics. We also analyze whether there is any incumbency advantage in offering to consumers both fixed-line and mobile services and to what extent the use of Internet technologies influences substitution or complementarity between mobile and fixed-line connections.

3 Data

Survey data We use five Special Eurobarometer surveys conducted in 27 EU countries by the TNS Opinion & Social Network on behalf of the European Commission. The surveys were

conducted in approximately 12 months intervals between December 2005 and March 2011, with the exception of the years 2008 and 2010.¹ The purpose of the 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.² A description of the sampling methodology and summary of the results for questions related to telecommunications services can be found in the Eurobarometer reports published on the website of the Commission. The Commission is granting access to Eurobarometer primary data for re-use in social science research and training. We have processed and combined these five surveys and selected variables which are relevant for our questions of interest. Table 1 provides a list of variables which we use in the estimation. Table A.1 in the Appendix shows the number of observations for each country used in the analysis. Tables A.2, A.3 and A.4 in the Appendix illustrate trends in the data with respect to usage of fixed-line and mobile connections.

Prices Data on prices of mobile and fixed-line telecommunications services comes from the reports on “Telecoms Price Developments” produced on annual 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,

¹The 2011 survey is from start of the year but the results should not be much different if it was conducted at the end of 2010 instead. We consider therefore that it is equivalent to 2010 survey for consistency with other surveys which were conducted at the end of each year.

²The surveys used in the analysis are: (i) Eurobarometer 64.4: Mental Well-Being, Telecommunications, Harmful Internet Content, and Farm Animal Welfare, December 2005 - January 2006; (ii) Eurobarometer 66.3: Social Reality, E-Communications, Common Agricultural Policy, Discrimination and the Media, and Medical Research, November - December 2006; (iii) Eurobarometer 68.2: European Union Policy and Decision Making, Corruption, Civil Justice, E-Communications, Agriculture, and Environmental Protection, November - December 2007; (iv) Eurobarometer 72.5: E-Communications, Agriculture, Geographical and Labor Market Mobility, and Knowledge of Antibiotic Use, November-December 2009; (v) Eurobarometer 75.1: Energy in the European Union, Citizens’ Rights, E-Communications, the Internal Market, and Carbon Dioxide Capture and Storage, February 2011 - March 2011.

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. Tariffs data were validated by the NRAs to ensure the reliability of information.³

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. Thus, the cost of the tariff is not necessarily the lowest on the market. Mobile prices are constructed 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.⁴

4 Econometric Model

We aim to model the households’ decisions whether to use fixed-line and/or mobile telephone services, and in an extension the role played by their internet technology decisions. A standard discrete choice framework is not suitable for such analysis because households may simultaneously choose more than one alternative: (i) they may use both fixed and mobile voice services, and (ii) these services can be combined with the use of certain internet technology. To incorporate the possibility that households may choose multiple options, we follow the approach of Gentzkow (2007) and formulate a discrete choice model for *bundles* of alternatives.

³We have combined Teligen’s pricing data with Eurobarometer data. Teligen data for years 2005-2010 was collected in September, which is a few months earlier than the Eurobarometer data, which was usually collected at 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; 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.

⁴The 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.

We first present the base model, where households choose only between voice services, and then extend the model to incorporate the simultaneous choice of internet technology.

4.1 Demand for voice services

A household i has available two possible voice services, indexed by j : fixed-line ($j = F$) and mobile ($j = M$). The choice set consists of the four possible bundles of these services, $r \in \{0, F, M, F + M\}$, where $r = 0$ refers to the choice of no telephone at all, and $r = F + M$ refers to the choice of both fixed and mobile services. Figure 1 shows the shares of these four choice alternatives across the 27 EU countries in March 2011. Table 2 illustrates choices of voice technologies in the whole sample.

Household i 's stand-alone utility for a connection to voice service j is:

$$\bar{u}_{ij} = x_i \beta_j + \alpha p_{ij},$$

where p_{ij} is the price paid by individual i for voice service j and x_i is a vector of household characteristics influencing the utility of the voice service. The price p_{ij} refers to the fixed subscription charge plus usage cost of a representative consumer. It may vary across consumers depending on the country, year, and type of contract (pre-paid versus post-paid).⁵ The vector of household characteristics x_i consists of three groups of variables: household demographics (such as sex, age, education, household size); employment status (such as student, retired or employment sector); and regional and time information (such country, regional GDP per capita, time effects).

A household's utility for a bundle of voice services $r \in \{0, F, M, F + M\}$ is:

$$\begin{aligned} u_{ir} &= \varepsilon_{ir} & \text{if } r = 0 \\ u_{ir} &= \sum_{j \in r} \bar{u}_{ij} + \Gamma_{ir} + \varepsilon_{ir}, & \text{if } r \neq 0 \end{aligned} \quad (1)$$

where $j \in r$ denotes the set of goods j included in bundle r . The term Γ_{ir} is the difference between the household's total utility for a bundle r and the sum of the stand-alone utilities

⁵There is information on pre-paid and post-paid prices only from for years 2008, 2009 and 2010.

$\bar{u}_{ij}$ for the services $j \in r$. For the singleton bundles, $r = F$ and $r = M$, we set $\Gamma_{ir} = 0$. For the real bundle $r = F + M$, the services are complements if $\Gamma_{ir} > 0$, they are substitutes if $\Gamma_{ir} < 0$, and they are independent if $\Gamma_{ir} = 0$. Gentzkow (2007) provides a discussion how price affects the marginal consumers in these three situations. Macher et al. (2012) adapt the model to the choice of telecommunications, but in a more restricted setting than ours. We specify $\Gamma_{ir} = x_i \gamma$, so we allow households to be heterogeneous in their valuation of the substitutability or complementarity of fixed and mobile services according to the same household characteristics that affect the stand-alone utilities for fixed and mobile voice (demographics, employment status and regional and time information). The terms ε_{ir} are i.i.d. type I extreme value, or the typical “logit” error terms.

Based on this specification, we obtain the following utilities for the four bundles

$$\begin{aligned} u_{i0} &= \varepsilon_{i0} \\ u_{iF} &= x_i \beta_F + \alpha p_{iF} + \varepsilon_{iF} \\ u_{iM} &= x_i \beta_M + \alpha p_{iM} + \varepsilon_{iM} \\ u_{iF+M} &= x_i (\beta_F + \beta_M + \gamma) + \alpha (p_{iF} + p_{iM}) + \varepsilon_{iF+M}. \end{aligned}$$

We can easily extend this framework to distinguish between the type of operator providing the voice service: incumbent or competitor. The index j now refers to voice service and operator type: incumbent fixed-line ($j = F_1$), competitor fixed-line ($j = F_2$), incumbent mobile ($j = M_1$), competitor mobile ($j = M_2$). The choice set then consists of nine possible bundles $r \in \{0, F_1, F_2, M_1, M_2, F_1 + M_1, F_1 + M_2, F_2 + M_1, F_2 + M_2\}$. The information on the name of operator used by the household is only available for 2005 and 2006, so we limit the analysis to these first two years of the survey. Table 3 shows that most households have a fixed line connection from the incumbent, and among those households there is roughly an equal number with a mobile connection from the incumbent or from a competitor. The number of households with a fixed line connection from an entrant is smaller. The utilities for the stand-alone alternatives j and for the bundles r take the same form as before. Since there is a large number of bundles we will impose restrictions on the number of interaction terms, as explained in the empirical

analysis.

4.2 Demand for voice services and internet technology

We now extend the framework to incorporate the households' choice of internet technology. Each household has available two voice services $j = \{F, M\}$ and six possible internet technology choices: (i) no internet, (ii) copper-based dial-up, or "narrowband"; (iii) copper-based DSL broadband; (iv) cable modem broadband; (v) mobile broadband; (vi) other broadband (usually fibre or WiFi), which we denote by $k = 0, 1, \dots, 5$. The households' choice set therefore consists of a maximum of 24 possible bundles of services: the 4 voice bundles $\{0, F, M, F + M\}$ times the 6 internet choices. In practice, however, 7 of the 24 alternatives are chosen by only a very small number of households (< 100), as shown in Table 4. First, there are almost no households without voice service but with an internet connection via any of technologies (5 alternatives). Second, there are also almost no households with a mobile or other internet connection and only a fixed-line voice service (2 alternatives). We therefore restrict the choice set to the remaining 17 alternatives and drop from the analysis the small number of households which selected any of the 7 alternatives which are not considered as viable in our analysis. In principle, households may choose more than one internet technology. However, as shown in Table 5, the incidence of such multihoming is rare, and we remove these households from the analysis.

A household's stand-alone utility for voice service j is the same as specified earlier in (1). The additional utility from combining fixed and mobile technology, $r = F + M$ is also specified as $\Gamma_{ir} = x_i \gamma$: if $\Gamma_{ir} > 0$ fixed and mobile are complements; they are substitutes if $\Gamma_{ir} < 0$; and they are independent if $\Gamma_{ir} = 0$. There is no "stand-alone" utility for an internet technology k because the remaining households always combine it with at least one voice service. We allow the households valuation for the specific internet technology to depend on the type of voice service. For example, households may keep a copper fixed-line connection because it may be also used to access Internet via dial-up or DSL. Conversely, households may give up their fixed-line connection for voice services when they access Internet via a cable modem, mobile

modem or fibre.⁶ To model this, let $\Delta_{ir,k}$ be the additional utility from adopting internet technology k when the household has adopted the voice service bundle $r \in \{F, M, F + M\}$. For example, $\Delta_{iF,1}$ is the additional utility from adopting copper-based dial-up ($k = 1$) when the household has a fixed-line. The most interesting terms are $\Delta_{iF+M,k}$, which measure to which extent internet technology k affects the complementarity/substitutability between fixed and mobile. We specify $\Delta_{ir,k} = \delta_{r,k} + x_i \delta_k$. The first term $\delta_{r,k}$ captures the valuations for combining the voice bundles with the various internet technologies, which is assumed to be homogeneous across household. The second term captures household heterogeneity for the valuation of having internet connection via any internet technology. To simplify, we assume that δ_k is the same for all internet connections $k > 0$ and denote it by $\delta_k = \delta_I$ for $k > 0$, so that it captures the valuations for any internet connection.

A household's utility for a bundle of voice services $r \in \{0, F, M, F + M\}$ in combination with an internet technology k can then be specified as:

$$\begin{aligned} u_{ir,k} &= \varepsilon_{ir,k} & \text{if } r = 0, k = 0 \\ u_{ir,k} &= \sum_{j \in r} \bar{u}_{ij} + \Gamma_{ir} + \Delta_{ir,k} + \varepsilon_{ir,k}, & \text{if } r \neq 0 \end{aligned}$$

where the terms $\varepsilon_{ir,k}$ are again the logit error terms.

This gives the following utilities

$$\begin{aligned} u_{i0,0} &= \varepsilon_{i0,0} \\ u_{iF,k} &= x_i (\beta_F + \delta_I) + \delta_{F,k} + \alpha p_{iF} + \varepsilon_{iF,k} \\ u_{iM,k} &= x_i (\beta_M + \delta_I) + \delta_{M,k} + \alpha p_{iM} + \varepsilon_{iM,k} \\ u_{iF+M,k} &= x_i (\beta_F + \beta_M + \gamma + \delta_I) + \delta_{F+M,k} + \alpha (p_{iF} + p_{iM}) + \varepsilon_{iF+M,k}. \end{aligned}$$

⁶Grzybowski (2013) uses the aggregate data from the Eurobarometer reports published by the European Commission to analyze fixed-to-mobile substitution. He reports that the share of 'fixed + mobile' households is positively correlated with percentage of households having broadband access and negatively correlated with the share of households having cable modem.

4.3 Choice Probabilities and Estimation

In the first model households choose the voice bundle r and in the second model households simultaneously choose the voice bundle r and internet technology k that maximizes random utility. We focus here on the second, more general model. Given that the $\varepsilon_{ir,k}$ are type I extreme value distributed, random utility maximization results in the following logit choice probabilities:

$$s_{ir,k} = \frac{\exp(V_{ir,k})}{1 + \sum_k \sum_r \exp(V_{ir,k})} \quad (2)$$

where $V_{ir,k} \equiv u_{ir,k} - \varepsilon_{ir,k}$ is the deterministic component of household i 's utility for voice bundle r and internet technology k .

In both the first model (voice bundles only) and the second model (voice bundles + internet), we take into account the geographic availability of the choice alternatives. First, while mobile voice services are universally available in all EU countries, fixed voice services may not always be available in rural areas, especially in the CEE countries. As a sensitivity analysis, we have therefore also estimated the models on a sub-sample of households living in large towns and cities, where fixed-line connection should be in general available. Second, certain types of broadband internet technologies may not be available in certain geographic areas or even in whole countries. In the second model, we therefore restrict the choice sets to those broadband technologies that are available in the region where the household lives. If there is not a single household which chooses a particular broadband technology in a given area, we assume that it is not available to all households in this area. This assumption still makes the choice set potentially too broad, because the fact that there are households using a particular broadband technology in a given geographic area does not imply that it is available to all other households in this area.

The choice probabilities (with suitably modified summations in the numerator of (2) to account for limited geographic availability) form the basis of the likelihood function that is taken to the data. Defining $y_{ir,k} = 1$ if household i selects voice bundle r and internet technology k ,

and $y_{ijk} = 0$ otherwise, the log likelihood function can be written as:

$$\mathcal{L}(\theta) = \sum_i^N \sum_{r,k} y_{ir,k} \log s_{ir,k}(\theta). \quad (3)$$

where θ is the vector of all parameters to be estimated. The maximum likelihood estimator is the value of the parameter vector θ that maximizes (3). The model allows for rich substitution patterns because of a large set of included observed household characteristics. We nevertheless also considered an extension of the model with unobserved household heterogeneity. This involves the typical random coefficients of the mixed logit model as in Train (2003), and suitable restrictions on these random coefficients for the bundled alternatives. We found that the standard deviations of the random coefficients were not significant, so we focus our analysis on the model with observed household heterogeneity.⁷

5 Empirical Results

In section 4.1 we present the empirical results for the base model, where households only choose between voice services (Table 6 and 8). Section 4.2 then considers the results from the extended model, where households simultaneously choose the voice service and the internet technology, if any (Table 7). In all specifications, we include a rich set of household characteristics. Summary statistics for these household characteristics are shown in Table 1.

5.1 Voice services

Table 6 shows the empirical results for the base model, where households only choose between voice services. The left part considers the simplest case, where the choice set is limited to 4 alternatives: $\{0, F, M, F + M\}$, i.e. households may either choose no telephone, fixed, mobile or both. The right part considers the extended choice set of 9 alternatives, $\{0, F_1, F_2, M_1, M_2,$

⁷The mixed logit model is estimated using simulated maximum likelihood, and takes considerable time to converge given the very large number of observations, choice alternatives and included observed household characteristics.

$F_1 + M_1, F_1 + M_2, F_2 + M_1, F_2 + M_2\}$. As discussed above, in this case households also decide whether to take fixed or mobile services from the incumbent (fixed-line) operator, or from a competitor. In both specifications, price has a negative and highly significant effect on utility. In addition to the price parameter, Table 6 reports three columns: the first and second columns give the stand-alone utilities for fixed-line and mobile voice services (β_F and β_M), and the third column shows the substitution or complementarity effects between fixed and mobile (γ). Table 6 only presents the main effects and the interactions with regional variables (regional income per capita and a dummy variable for the group of CEE countries). Table 8 shows the interactions with the household characteristics for the first specification. The estimated household interactions for the second specification (and our subsequent extension to broadband choice) are very similar, so we only present them in the Appendix.

We focus most of our discussion on the estimated substitution/complementarity effects (parameter vector γ), but also briefly comment on the stand-alone effects (β_F and β_M).

Regional differences and evolution According to Table 6, households who live in richer regions are more likely to have both mobile and fixed-line connections (positive and strongly significant β_F and β_M). Furthermore, households from the CEE countries are more likely to have mobile, but less likely to have fixed-line connections than households from the WE countries (after controlling for regional income and other household characteristics). Finally, the adoption of mobile phones is still increasing over time (during 2006-2011), whereas the adoption of fixed-line services shows limited variation across years.

Our main interest is in the substitution/complementarity effects (γ). We find that the estimated intercept is negative and highly significant. This means that households on average tend to view fixed-line and mobile voice as substitutes. Notice however that the degree of substitution was considerably weaker during the first three years of our study (2006-2008). This suggests that the two technologies have only recently converged.

Furthermore, one can observe interesting differences in substitution effects across regions. There is stronger substitution in countries with a high regional income per capita and in the CEE

countries (negative and significant effect in γ). The stronger substitution in the CEE countries (after controlling for regional income and differences in household characteristics) may be due to the lower quality of the fixed network than in the WE countries.

To obtain a more detailed picture on the differences in substitution across countries, we estimated an extended model, where we allow country specific fixed effects in γ (and also in β_F and β_M). Figure 2 shows how the degree of substitution differs across countries, independent of income and household characteristics. Fixed-line and mobile services are strong substitutes in countries such as Romania, Finland, Lithuania or the Czech Republic. In contrast, they are weak complements in countries such as Sweden, the Netherlands and Malta. In the UK, Luxembourg and Slovenia, both technologies are independent from each other.

The role of household characteristics We again first have a brief look at the effects of household characteristics on the stand-alone utilities for fixed-line and mobile voice services (β_F and β_M). City households have a higher valuation for both fixed-line and mobile voice services than households in smaller towns and rural areas. The same is true for married households, for larger households with a small number of kids below age 15, and for more educated households. Males and younger households also have a higher valuation for mobile phones, but they have a lower valuation for a fixed-line connection. There are also significant differences in the stand-alone valuations for mobile and fixed-line across different professional groups.

We now discuss how household characteristics influence the perceived substitutability between fixed-line and mobile services. We find that there is substantial heterogeneity across households. Households who live in cities are more likely to substitute to mobile than rural households. Males and highly educated people are also more likely to substitute, while large households and households with many kids below 15 are less likely to substitute. Households with the head of household between 25 and 34 are less likely to substitute than other age groups. There are also significant differences in substitution across different professional groups. Proprietors and travelling professions consider fixed-line and mobile as stronger substitutes, and households with non-working, housekeeping members tend to view fixed-line and mobile as

complementary.

Incumbent versus competitor The right part of Table 6 shows the empirical results for the model with the expanded choice set, which makes a distinction between having a fixed-line or mobile connection from the incumbent or a competitor. This model only uses data for years 2006 and 2007, because information about the operator used by the households is only available for these years. The impact of household characteristics is similar to the previous model (shown in Table 8), so we only present these results in the Appendix. Substitution between fixed and mobile is weaker, which is mainly because we consider only 2006 and 2007.

The most interesting new finding relates to the role of the incumbency status. Not surprisingly, households have a considerably higher valuation for a fixed-line connection at the incumbent fixed-line operator (second column). This simply reflects the fact that the incumbent operator is the dominant provider of fixed-line services and owns most of the fixed telephony network, to which competitors need to obtain access. Furthermore, households tend to have a lower valuation for a mobile connection that is offered by the incumbent (first column). This reflects the fact that most European countries have strongly promoted competition in the mobile telephony market through the policy of granting licences to develop mobile networks.. Even though the incumbent was typically granted a mobile licence early on, the competitors altogether tend to have greater market share than the incumbent. In three countries, Lithuania, Romania and UK, the incumbent did not receive a mobile licence at all. Most interestingly, households perceive the fixed-line and mobile voice services offered by the incumbent as strong complements (third column). In this sense, we can conclude that the incumbent fixed-line operator has an advantage in the mobile market. Since the fixed-line incumbent in almost all of the EU countries has a dominant position in the fixed telephony market, he has the possibility to leverage this position into the mobile telephony market.

5.2 Voice services and internet technology

Table 7 shows the empirical results for the model that considers the simultaneous choice of voice and Internet technology. As discussed in Section 4, there are now 17 choice alternatives: the 4 voice bundles $\{0, F, M, F + M\}$, which may be combined with at most 6 possible Internet choices (including no Internet). In addition to the stand-alone utilities for voice (β_F and β_M) and substitution/complementarity effects between fixed and mobile (γ), we now also estimate how household characteristics influence Internet adoption (δ_I), and how the substitution/complementary between fixed and mobile depends on the choice of Internet technology ($\delta_{r,k}$). The estimates for the stand-alone utilities and substitution effects (β_F , β_M and γ) are comparable to our base model, so we do not discuss them again in detail.

Our main findings relate to the question how internet adoption affects fixed to mobile substitution. Based on Table 7, this can be summarized as follows. Without Internet, mobile and fixed-line voice services are perceived as substitutes, and this is more so in the CEE countries than in the WE countries (as already found above). Furthermore, the estimates show that mobile and fixed-line voice services are even stronger substitutes when combined with mobile broadband Internet. In sharp contrast, having a fixed Internet connection (DSL, cable and dial-up) makes mobile and fixed-line access strongly complementary. In other words, while households consider that fixed-line and mobile voice services are intrinsically substitutes, they become complements once they are combined with the adoption of fixed broadband internet access. Households which access Internet via DSL have to pay for maintaining copper connection, which also typically includes fixed-line services at small or no additional cost. Dial-up access per se requires fixed-line subscription. On the other hand, Internet technologies such as fibre, cable modem, WiFi and mobile do not require households to have copper line connection, which may be considered as obsolete.

Note that our model also included interactions of household characteristics with Internet access dummy (δ_I). These results are shown in the Appendix, and we briefly review them here. First, households living in the cities and smaller towns are more likely to use Internet, as

compared to households from rural areas. Males and married households are more likely to have Internet access. The same is true for larger households, households with many kids, younger and highly educated households.

6 Conclusion

In this paper we use survey data on 133,825 households from 27 EU countries in years 2005-2011 to analyze substitution between access to fixed-line and mobile telecommunications services. We estimate discrete choice models in which households can choose between access to fixed-line and/or mobile voice services.

We consider three model specifications. In the first model specification, households only choose between voice services where the choice set consists of 4 alternatives: no telephone, fixed, mobile or both. In the second specification, households choose between voice services from the fixed-line incumbent operator or from competitors, so that the choice set is extended to 9 alternatives. In the third model specification, households simultaneously choose voice and Internet technology. There are 17 choice alternatives in this case: the 4 choices of voice from the first specification, which may be combined with at most 6 Internet technology choices (including having no Internet).

We find that households on average tend to view fixed-line and mobile voice as substitutes. But household characteristics influence the perceived substitutability, so that for some household characteristics fixed-line and mobile connections are substitutes, while they are complements for others. There are interesting differences in substitution effects across regions. There is stronger substitution in regions with a high income per capita and in the CEE countries. The stronger substitution in the CEE countries (after controlling for regional income and differences in household characteristics) may be due to the lower quality of the fixed network than in the WE countries. In an extended model with country-specific substitution parameters we find that the degree of substitution differs across countries, independent of the level of income and household characteristics. Fixed-line and mobile services are strong substitutes in countries such

as Romania, Finland, Lithuania or the Czech Republic. In contrast, they are weak complements in countries such as Sweden, the Netherlands and Malta. In the UK, Luxembourg and Slovenia, both technologies are independent from each other.

In the second model specification, which makes a distinction between having a fixed-line or mobile connection from the incumbent and competitors, the substitution between fixed-line and mobile is weaker. This is mainly because we miss operator information for some years and estimate the model only for years 2006 and 2007. In addition to confirming results from the first model, we find that households perceive the fixed-line and mobile voice services offered by the incumbent as strong complements. We can therefore conclude that the incumbent fixed-line operator has an advantage in the mobile market. Since the fixed-line incumbent in almost all of the EU countries has a dominant position in the fixed telephony market, he has the possibility to leverage this position into the mobile telephony market.

In the third model specification with simultaneous choice of voice and Internet technology we conclude how internet adoption affects fixed-to-mobile substitution. We find as before that without Internet, mobile and fixed-line voice services are perceived as substitutes. Furthermore, the estimates show that mobile and fixed-line voice services are even stronger substitutes when combined with mobile broadband Internet. In sharp contrast, having a fixed Internet connection (DSL, cable and dial-up) makes mobile and fixed-line access strongly complementary. In other words, while households consider fixed-line and mobile voice services intrinsically as substitutes, they become complements once they are combined with the adoption of fixed broadband internet access. This shows that the incumbent cannot only leverage its advantage to mobile voice services, but also to broadband since the incumbent typically owns the fixed copper network infrastructure.

These results suggest that policies towards regulation of broadband market have an impact on the market structure of voice services. We can in general distinguish between two regulatory approaches which result in different market structures of broadband services. One approach is to promote competition on the incumbent's copper network through regulation which pro-

vides entrants with access to incumbent's infrastructure via local loop unbundling (service-based competition).⁸ Another approach is to promote deployment and competition between different broadband platforms such as cable modem, fibre, WiFi and more recently mobile broadband (infrastructure-based competition). Some countries opted for service-based competition resulting in high market share of DSL connections, while other pursued infrastructure-based competition with a high market share of other broadband technologies. In future work, it would be interesting to perform policy counterfactuals to our model to evaluate the impact of these alternative policies on voice and broadband adoption.

⁸Local loop unbundling is the regulatory process of allowing multiple telecommunications operators to use connections from the telephone exchange to the customer's premises.

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Tables and Figures

Figure 1: Shares of voice technologies across the EU countries

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

Figure 2: Estimates for substitution/complementarity between fixed-line and mobile connections across the EU countries in March 2011

Table 1: Summary statistics

Variable	Obs.	Mean	Std	Min	Max
Cost of mobile	133,825	10,90	4,98	1,18	29,7
Cost of fixed-line	133,825	36,90	7,64	16,3	57,4
Male	133,825	0,45	0,50	0	1
Married	133,825	0,52	0,50	0	1
Age <= 24 (base)	133,825	0,12	0,33	0	1
Age > 24 and <= 34	133,825	0,15	0,36	0	1
Age > 34 and <= 44	133,825	0,17	0,38	0	1
Age > 44 and <= 54	133,825	0,17	0,38	0	1
Age > 54 and <= 64	133,825	0,17	0,37	0	1
Age > 64	133,825	0,22	0,41	0	1
Household size	133,825	2,51	1,10	1	4
Number of kids	133,699	0,16	0,45	0	4
Education years <= 15	133,825	0,21	0,40	0	1
Education years > 15 and < 20	133,825	0,43	0,49	0	1
Education years 20+	133,825	0,26	0,44	0	1
Living in rural area (base)	133,825	0,36	0,48	0	1
Living in town	133,825	0,36	0,48	0	1
Living in city	133,825	0,28	0,45	0	1
Profession: unemployed (base)	133,825	0,08	0,28	0	1
Profession: housekeeping	133,825	0,07	0,25	0	1
Profession: student	133,825	0,08	0,27	0	1
Profession: retired	133,825	0,29	0,45	0	1
Profession: office employee	133,825	0,08	0,27	0	1
Profession: professional	133,825	0,04	0,19	0	1
Profession: manual worker	133,825	0,14	0,34	0	1
Profession: proprietor	133,825	0,04	0,20	0	1
Profession: manager	133,825	0,07	0,26	0	1
Profession: farmer	133,825	0,01	0,11	0	1
Profession: travelling	133,825	0,10	0,30	0	1
TV reception: aerial	133,825	0,37	0,48	0	1
TV reception: cable	133,825	0,43	0,49	0	1
TV reception: digital	133,825	0,11	0,31	0	1
TV reception: satellite	133,825	0,17	0,37	0	1
Internet access: DSL	133,825	0,25	0,43	0	1
Internet access: cable	133,825	0,11	0,31	0	1
Internet access: dial-up	133,825	0,09	0,28	0	1
Internet access: mobile	133,825	0,03	0,16	0	1

Base variable is indicated for dummy variables. In the case of Education years dummies, the reference are households without education or with missing information.

Table 2: Choice of voice technologies

		Fixed-line		
		No	Yes	Total
Mobile	No	5143	37267	42410
	Yes	17517	73743	91260
	Total	22660	111010	133670

Table 3: Choice of voice technologies offered by incumbent and competitor

		Fixed-line			
		None	Incumbent	Competitor	Total
Mobile	None	3,297	8,459	835	12,591
	Incumbent	4,091	10,227	1,423	15,741
	Competitor	8,993	12,995	3,086	25,074
	Total	16,381	31,681	5,344	53,406

Table 4: Choice of voice and broadband technologies

	DSL	Dial-up	Cable modem	Mobile	Other	None	Total
Mobile only	4,712	798	5,252	2,039	2,054	22,894	37,749
Fixed-line only	1,124	674	392	35	94	15,272	17,591
Mobile+ Fixed-line	26,982	10,167	8,747	1,583	1,905	26,283	75,667
None	57	20	71	12	20	4,967	5,147
Total	32875	11,659	14,462	3,669	4,073	69,416	136,154

Table 5: Multihoming of broadband technologies

	DSL	Dial-up	Cable modem	Mobile	Other
DSL	31,166	611	226	722	105
Dial-up	611	10,678	105	118	46
Cable modem	226	105	13,795	272	60
Mobile	722	118	272	2,488	64
Other	105	46	60	64	3,612

Table 6: Choice model for voice services

	Base model			Base model + Incumbent		
	Mobile	Fixed-line	Gamma	Mobile	Fixed-line	Gamma
Price	-0.042*** (0.001)	-0.042*** (0.001)		-0.042*** (0.001)	-0.042*** (0.001)	
Intercept	0.596*** (0.113)	2.633*** (0.115)	-0.715*** (0.125)	-1.250*** (0.148)	0.492*** (0.142)	-0.174 (0.166)
CEE dummy	0.1729*** (0.049)	-0.5839*** (0.051)	-0.416*** (0.041)	-0.311*** (0.076)	-1.013*** (0.076)	0.104 (0.085)
Regional income per capita	1.2999*** (0.028)	1.1120*** (0.030)	-0.6935*** (0.033)	0.871*** (0.050)	0.482*** (0.049)	-0.240*** (0.056)
Incumbent				-0.517*** (0.017)	1.334*** (0.016)	0.396*** (0.021)
Year dummy: 2006	-1.379*** (0.056)	0.221*** (0.058)	0.327*** (0.061)	-0.214*** (0.043)	0.209*** (0.043)	0.056 (0.047)
Year dummy: 2007	-1.161*** (0.055)	-0.035 (0.058)	0.274*** (0.061)			
Year dummy: 2008	-0.897*** (0.056)	-0.121** (0.060)	0.284*** (0.063)			
Year dummy: 2009	-0.210*** (0.061)	0.179*** (0.065)	-0.136** (0.067)			
Observations	534,176			405,902		

Base model: choices of voice connections with substitution parameters for two groups of CEE and WE countries. The regressions include household characteristics which are reported in Table 8. Base model + incumbent: choices of voice connections from incumbent vs. competitor. The regression include household characteristics which are reported in Table A.5.

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7: Choice model for voice services and broadband Internet

	Base model + Broadband			
	Mobile	Fixed-line	Gamma	Broadband
Price	-0.041*** (0.001)	-0.041*** (0.001)		
Intercept	0.426*** (0.115)	2.452*** (0.117)	-0.839*** (0.127)	
CEE dummy	0.174*** (0.030)	-0.556*** (0.036)	-0.453*** (0.041)	
Regional income per capita	1.313*** (0.029)	1.129*** (0.031)	-0.846*** (0.034)	0.028*** (0.001)
DSL connection	-4.086*** (0.068)	-3.808*** (0.072)	5.603*** (0.074)	
Cable connection	-3.964*** (0.067)	-4.849*** (0.083)	6.943*** (0.085)	
Dial-up connection	-5.902*** (0.076)	-4.335*** (0.076)	6.943*** (0.085)	
Mobile broadband	-5.041*** (0.070)		-0.804*** (0.046)	
Other broadband	-4.910*** (0.070)		-0.080** (0.035)	
Year dummy: 2006	-1.280*** (0.058)	0.334*** (0.060)	0.563*** (0.064)	-1.513*** (0.023)
Year dummy: 2007	-1.058*** (0.058)	0.076 (0.061)	0.463*** (0.064)	-1.301*** (0.022)
Year dummy: 2008	-0.804*** (0.059)	-0.025 (0.062)	0.396*** (0.065)	-0.920*** (0.022)
Year dummy: 2009	-0.144** (0.064)	0.234*** (0.067)	-0.061 (0.070)	-0.594*** (0.022)
Observations	2,225,776			

Base model + Broadband: choices of voice and broadband connections. The regression include household characteristics which are reported in Table A.5.

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Choice model for voice services: estimates of household characteristics

	Base model		
	Mobile	Fixed-line	Gamma
Living in city	0.761*** (0.046)	0.642*** (0.047)	-0.490*** (0.050)
Living in town	0.529*** (0.037)	0.272*** (0.038)	-0.341*** (0.041)
Male	-0.355*** (0.034)	-0.566*** (0.036)	0.541*** (0.038)
Married	0.395*** (0.040)	0.342*** (0.041)	-0.157*** (0.044)
Household size	0.131*** (0.022)	0.320*** (0.024)	0.089*** (0.025)
Number of kids	-0.122*** (0.047)	-0.284*** (0.054)	0.148*** (0.056)
Age > 24 and <= 34	2.085*** (0.101)	-2.295*** (0.130)	0.435*** (0.135)
Age > 34 and <= 44	2.062*** (0.083)	-2.086*** (0.096)	0.151 (0.101)
Age > 44 and <= 54	1.582*** (0.078)	-1.515*** (0.084)	0.006 (0.090)
Age > 54 and <= 64	1.145*** (0.066)	-1.000*** (0.068)	-0.038 (0.075)
Age > 64	0.954*** (0.050)	-0.446*** (0.049)	-0.084 (0.056)
Education years 15-	0.370*** (0.077)	0.282*** (0.073)	-0.134 (0.088)
Education years > 15 and <= 20	1.114*** (0.077)	0.757*** (0.075)	-0.210** (0.088)
Education years 20+	1.664*** (0.092)	1.254*** (0.091)	-0.390*** (0.102)
Profession: housekeeping	-0.072 (0.076)	-0.526*** (0.086)	0.206** (0.091)
Profession: student	2.036*** (0.145)	1.329*** (0.178)	-0.242 (0.186)
Profession: retired	0.191*** (0.070)	0.067 (0.069)	-0.053 (0.075)
Profession: office employee	1.379*** (0.130)	0.589*** (0.140)	-0.320** (0.143)
Profession: professional	1.251*** (0.176)	0.250 (0.194)	0.189 (0.197)
Profession: manual worker	0.763*** (0.075)	0.111 (0.081)	-0.263*** (0.085)
Profession: proprietor	1.887*** (0.190)	1.148*** (0.200)	-0.761*** (0.203)
Profession: manager	1.295*** (0.152)	0.711*** (0.160)	-0.384** (0.163)
Profession: farmer	-0.080 (0.121)	0.345*** (0.125)	0.031 (0.139)
Profession: travelling	1.378*** (0.112)	0.652*** (0.119)	-0.591*** (0.123)
Observations	534,176		

Base model: choices of voice connections with substitution parameters for two groups of CEE and WE countries.

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix

Table A.1: Sample size by country

	2005	2006	2007	2009	2011	Sum
Austria	1,019	1,029	1,012	1,001	1,030	5,091
Belgium	1,011	1,009	1,004	1,003	1,025	5,052
Bulgaria	1,002	1,023	1,000	1,007	1,001	5,033
Cyprus	507	504	505	502	500	2,518
Czech Republic	1,012	1,150	1,169	1,096	1,014	5,441
Germany	1,515	1,504	1,519	1,522	1,622	7,682
Denmark	1,039	1,037	1,000	1,008	1,013	5,097
Estonia	1,000	1,000	1,002	1,000	1,003	5,005
Greece	999	1,000	1,000	1,000	1,000	4,999
Spain	1,000	1,000	1,000	1,023	1,004	5,027
Finland	1,023	1,028	1038	1041	1,001	5,131
France	1,031	1,012	1,024	1,005	1,035	5,107
Hungary	1,010	1,000	1,000	1,017	1,029	5,056
Ireland	1,000	1,000	1,000	1,014	1,007	5,021
Italy	1,011	1,038	1,039	1,039	1,027	5,154
Lithuania	1,022	1,025	1,018	1,027	1,029	5,121
Luxembourg	500	502	500	502	503	2,507
Latvia	1,046	1,019	1,009	1,004	1,014	5,092
Malta	500	500	500	500	500	2,500
Netherlands	1,127	1,020	1,000	1,004	1,012	5,163
Poland	1,000	1,000	1,000	1,000	1,000	5,000
Portugal	1,004	1,004	1,000	1,038	1,010	5,056
Romania	1,003	1,000	1,000	1,008	1,053	5,064
Sweden	1,009	1,014	1,015	1,014	1,024	5,076
Slovenia	1,028	1,019	1,016	1,017	1,018	5,098
Slovakia	1,015	1,003	1,055	1,047	1,040	5,160
United Kingdom	1,310	1,315	1,305	1,322	1,322	6,574
Sum	28,748	28,761	28,737	28,770	28,847	133,825

Table A.2: Households with fixed-line access by country (%)

Country	2005	2006	2007	2009	2011
Austria	0.69	0.58	0.58	0.50	0.48
Belgium	0.77	0.69	0.68	0.67	0.70
Bulgaria	0.68	0.70	0.65	0.62	0.51
Cyprus	0.91	0.88	0.89	0.84	0.85
Czech Republic	0.54	0.44	0.35	0.24	0.17
Germany	0.88	0.89	0.87	0.89	0.88
Denmark	0.86	0.84	0.80	0.73	0.68
Estonia	0.63	0.52	0.60	0.54	0.51
Greece	0.87	0.83	0.83	0.80	0.84
Spain	0.77	0.76	0.73	0.70	0.72
Finland	0.57	0.51	0.44	0.33	0.26
France	0.86	0.80	0.85	0.90	0.89
Hungary	0.68	0.48	0.45	0.54	0.49
Ireland	0.83	0.76	0.82	0.73	0.69
Italy	0.68	0.53	0.58	0.69	0.66
Lithuania	0.44	0.39	0.38	0.42	0.36
Luxembourg	0.96	0.95	0.97	0.93	0.93
Latvia	0.56	0.47	0.52	0.48	0.49
Malta	0.98	0.97	0.96	0.98	0.98
Netherlands	0.97	0.94	0.93	0.91	0.91
Poland	0.71	0.69	0.65	0.55	0.49
Portugal	0.56	0.63	0.43	0.54	0.61
Romania	0.53	0.42	0.47	0.45	0.42
Sweden	1.00	0.98	0.98	0.99	0.98
Slovenia	0.87	0.87	0.84	0.83	0.84
Slovakia	0.59	0.53	0.49	0.41	0.38
United Kingdom	0.90	0.88	0.87	0.82	0.87

Table A.3: Households with mobile access by country (%)

Country	2005	2006	2007	2009	2011
Austria	0.80	0.82	0.89	0.90	0.92
Belgium	0.81	0.85	0.85	0.88	0.91
Bulgaria	0.47	0.53	0.62	0.77	0.82
Cyprus	0.76	0.72	0.83	0.90	0.93
Czech Republic	0.88	0.90	0.93	0.94	0.96
Germany	0.75	0.78	0.81	0.80	0.85
Denmark	0.85	0.85	0.91	0.92	0.95
Estonia	0.75	0.82	0.85	0.90	0.93
Greece	0.68	0.70	0.75	0.81	0.90
Spain	0.74	0.76	0.76	0.86	0.87
Finland	0.92	0.91	0.93	0.94	0.96
France	0.75	0.75	0.77	0.82	0.85
Hungary	0.68	0.68	0.75	0.80	0.86
Ireland	0.82	0.86	0.89	0.92	0.94
Italy	0.89	0.89	0.92	0.95	0.93
Lithuania	0.70	0.77	0.82	0.90	0.93
Luxembourg	0.86	0.88	0.91	0.90	0.95
Latvia	0.72	0.79	0.86	0.91	0.95
Malta	0.73	0.80	0.79	0.85	0.89
Netherlands	0.88	0.90	0.91	0.94	0.95
Poland	0.59	0.65	0.72	0.78	0.84
Portugal	0.64	0.77	0.77	0.81	0.84
Romania	0.50	0.62	0.66	0.74	0.85
Sweden	0.95	0.92	0.93	0.93	0.95
Slovenia	0.87	0.82	0.85	0.91	0.91
Slovakia	0.73	0.80	0.83	0.91	0.91
United Kingdom	0.80	0.81	0.85	0.85	0.90

Table A.4: Households with fixed-line and mobile access by country (%)

Country	2005	2006	2007	2009	2011
Austria	0.51	0.43	0.49	0.41	0.41
Belgium	0.60	0.57	0.56	0.56	0.62
Bulgaria	0.33	0.37	0.44	0.47	0.41
Cyprus	0.68	0.60	0.72	0.74	0.78
Czech Republic	0.45	0.37	0.31	0.21	0.16
Germany	0.65	0.68	0.69	0.70	0.74
Denmark	0.71	0.71	0.72	0.65	0.63
Estonia	0.44	0.39	0.49	0.47	0.46
Greece	0.57	0.55	0.59	0.62	0.74
Spain	0.54	0.56	0.54	0.59	0.60
Finland	0.49	0.43	0.37	0.28	0.23
France	0.62	0.58	0.64	0.73	0.74
Hungary	0.43	0.30	0.31	0.39	0.41
Ireland	0.67	0.65	0.72	0.66	0.64
Italy	0.58	0.47	0.52	0.65	0.61
Lithuania	0.26	0.29	0.29	0.36	0.31
Luxembourg	0.82	0.83	0.87	0.83	0.88
Latvia	0.37	0.36	0.42	0.42	0.46
Malta	0.72	0.77	0.76	0.83	0.87
Netherlands	0.85	0.84	0.84	0.85	0.87
Poland	0.41	0.42	0.43	0.39	0.38
Portugal	0.33	0.46	0.33	0.42	0.51
Romania	0.28	0.28	0.32	0.33	0.35
Sweden	0.95	0.91	0.92	0.92	0.93
Slovenia	0.75	0.70	0.72	0.75	0.76
Slovakia	0.40	0.39	0.37	0.35	0.31
United Kingdom	0.71	0.71	0.73	0.68	0.78

Table A.5: Estimates of household characteristics

	Base model + country effects			Base model + Incumbent			Base model + Broadband			
	Mobile	Fixed-line	Gamma	Mobile	Fixed-line	Gamma	Mobile	Fixed-line	Gamma	Broadband
Living in city	0.7204*** (0.046)	0.6093*** (0.047)	-0.4302*** (0.050)	0.760*** (0.059)	0.552*** (0.059)	-0.483*** (0.065)	0.771*** (0.047)	0.653*** (0.048)	-0.546*** (0.051)	0.183*** (0.018)
Living in town	-0.1183** (0.047)	-0.2847*** (0.054)	0.1576*** (0.056)	0.501*** (0.049)	0.253*** (0.049)	-0.335*** (0.055)	0.525*** (0.038)	0.265*** (0.039)	-0.377*** (0.042)	0.187*** (0.016)
Male	2.1110*** (0.101)	-2.2801*** (0.130)	0.5034*** (0.136)	-0.160*** (0.046)	-0.411*** (0.046)	0.458*** (0.051)	-0.383*** (0.035)	-0.603*** (0.037)	0.510*** (0.039)	0.271*** (0.015)
Married	0.3736*** (0.040)	0.3421*** (0.041)	-0.0645 (0.044)	0.315*** (0.052)	0.254*** (0.052)	-0.044 (0.058)	0.397*** (0.040)	0.340*** (0.042)	-0.186*** (0.044)	0.157*** (0.017)
Household size	0.1307*** (0.022)	0.3165*** (0.024)	0.0740*** (0.025)	0.068** (0.029)	0.348*** (0.031)	0.082** (0.033)	0.115*** (0.023)	0.301*** (0.025)	0.045* (0.026)	0.258*** (0.009)
Number of kids	-0.1183** (0.047)	-0.2847*** (0.054)	0.1576*** (0.056)	-0.119** (0.060)	-0.270*** (0.066)	0.135* (0.070)	-0.139*** (0.049)	-0.297*** (0.056)	0.147** (0.058)	0.049*** (0.017)
Age > 24 and <= 34	2.1110*** (0.101)	-2.2801*** (0.130)	0.5034*** (0.136)	2.640*** (0.136)	-2.035*** (0.170)	0.194 (0.181)	2.029*** (0.104)	-2.323*** (0.133)	0.181 (0.138)	1.249*** (0.042)
Age > 34 and <= 44	2.0974*** (0.083)	-2.0803*** (0.096)	0.1989* (0.102)	2.483*** (0.110)	-1.723*** (0.123)	-0.049 (0.134)	2.016*** (0.085)	-2.119*** (0.099)	-0.089 (0.104)	1.212*** (0.035)
Age > 44 and <= 54	1.6071*** (0.078)	-1.5096*** (0.084)	0.0841 (0.090)	1.862*** (0.104)	-1.258*** (0.108)	-0.099 (0.121)	1.505*** (0.080)	-1.585*** (0.086)	-0.187** (0.092)	1.193*** (0.034)
Age > 54 and <= 64	1.1489*** (0.066)	-1.0001*** (0.068)	0.0379 (0.075)	1.399*** (0.089)	-0.725*** (0.087)	-0.204** (0.102)	1.093*** (0.067)	-1.046*** (0.069)	-0.224*** (0.076)	1.075*** (0.032)
Age > 64	0.9561*** (0.051)	-0.4434*** (0.049)	-0.0287 (0.056)	1.020*** (0.069)	-0.323*** (0.062)	-0.057 (0.078)	0.925*** (0.051)	-0.475*** (0.049)	-0.208*** (0.056)	0.770*** (0.027)
Education years 15-	0.3574*** (0.077)	0.3115*** (0.073)	-0.3503*** (0.089)	0.685*** (0.110)	0.508*** (0.094)	-0.460*** (0.128)	0.407*** (0.078)	0.334*** (0.074)	-0.054 (0.089)	-0.525*** (0.052)
Education years > 15 and <= 20	1.1236*** (0.077)	0.7923*** (0.075)	-0.4350*** (0.089)	1.360*** (0.110)	0.972*** (0.098)	-0.531*** (0.128)	1.102*** (0.078)	0.749*** (0.076)	-0.230*** (0.089)	0.192*** (0.050)
Education years 20+	1.6783*** (0.092)	1.2835*** (0.091)	-0.5699*** (0.103)	1.665*** (0.123)	1.361*** (0.113)	-0.551*** (0.141)	1.629*** (0.096)	1.230*** (0.094)	-0.565*** (0.106)	0.893*** (0.051)
Profession: housekeeping	-0.0539 (0.076)	-0.5565*** (0.086)	0.2998*** (0.092)	-0.062 (0.102)	-0.487*** (0.110)	0.081 (0.123)	-0.073 (0.077)	-0.526*** (0.087)	0.230** (0.093)	-0.079** (0.036)
Profession: student	2.0446*** (0.145)	1.3325*** (0.178)	-0.2715 (0.187)	1.842*** (0.188)	1.313*** (0.222)	-0.354 (0.242)	1.792*** (0.155)	1.111*** (0.186)	-0.340* (0.194)	1.334*** (0.063)
Profession: retired	0.2188*** (0.070)	0.0467 (0.069)	0.0763 (0.077)	0.226** (0.092)	0.050 (0.086)	-0.138 (0.101)	0.218*** (0.070)	0.090 (0.069)	-0.062 (0.076)	-0.032 (0.032)
Profession: office employee	1.4075*** (0.130)	0.6021*** (0.140)	-0.2002 (0.144)	1.240*** (0.163)	0.589*** (0.174)	-0.220 (0.181)	1.405*** (0.145)	0.608*** (0.154)	-0.505*** (0.157)	0.627*** (0.034)
Profession: professional	1.2671*** (0.176)	0.2386 (0.194)	0.3534* (0.198)	1.220*** (0.210)	0.247 (0.229)	0.189 (0.238)	1.057*** (0.192)	0.060 (0.209)	0.150 (0.212)	0.915*** (0.045)
Profession: manual worker	0.7829*** (0.075)	0.0735 (0.081)	-0.0840 (0.086)	0.634*** (0.097)	0.026 (0.101)	-0.242** (0.111)	0.781*** (0.077)	0.115 (0.082)	-0.276*** (0.086)	0.025 (0.031)
Profession: proprietor	1.9053*** (0.190)	1.1221*** (0.200)	-0.5616*** (0.203)	1.397*** (0.209)	0.885*** (0.219)	-0.461** (0.227)	2.023*** (0.221)	1.293*** (0.229)	-1.061*** (0.232)	0.619*** (0.040)
Profession: manager	1.2989*** (0.152)	0.6994*** (0.160)	-0.2591 (0.164)	1.055*** (0.177)	0.479** (0.186)	-0.072 (0.194)	1.216*** (0.178)	0.692*** (0.184)	-0.595*** (0.187)	0.980*** (0.038)
Profession: farmer	-0.0305 (0.122)	0.3264*** (0.125)	0.1143 (0.140)	-0.386** (0.172)	0.197 (0.161)	0.181 (0.198)	-0.020 (0.122)	0.394*** (0.126)	0.093 (0.140)	-0.468*** (0.067)
Profession: travelling	1.3947*** (0.112)	0.6315*** (0.119)	-0.4407*** (0.123)	1.185*** (0.139)	0.537*** (0.147)	-0.449*** (0.154)	1.386*** (0.120)	0.668*** (0.127)	-0.730*** (0.130)	0.486*** (0.032)
Observations	534,176			405,902			2,225,776			

Base model + country effects: choices of voice connections with country-specific substitution parameters. Base model + Incumbent: choices of voice connections from incumbent vs. competitor. Base model + Broadband: choices of voice and broadband connections.

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$