Estimating demand for fixed-mobile bundles and switching costs between tariffs

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Abstract

This paper estimates demand for fixed-mobile bundles (quadruple play tariffs) using a database of subscribers to a single mobile operator from a single town in a European country which has full coverage with both ADSL and FTTH broadband technologies. Based on the demand estimation we find that consumer valuation of FTTH broadband in 2013 increased over time while ADSL lost on attractiveness relative to FTTH but also in absolute terms, which suggests that consumers increasingly care about the speed of connection offered by FTTH. The consumer surplus increased substantially due to ongoing transition of consumers from less valued quadruple play tariffs with ADSL to more valued with FTTH. We also find that for quadruple play subscribers mobile data is complementary to fixed broadband access, which suggests that these consumers use Internet access via mobile data to sample online content but they complete their online activity using fixed Internet access at home. On the other hand, mobile voice usage is a substitute to fixed broadband access and consumers reduce their voice consumption once they get broadband connection. We also find that there are substantial switching costs between tariffs, which other things being equal, greatly decrease consumer surplus.

Key Words: *Quadruple play; FTTH; ADSL; Mobile data; Switching costs*

JEL Classification: L13, L50, L96

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1 Introduction

In the last years many telecommunications operators in Europe introduced fixed-mobile bundles (quadruple play tariffs) which include mobile voice and data, fixed IP voice, fixed broadband and IP TV. The number of households using bundled offers has been growing rapidly since then.[1]

The introduction of these offers raises some questions. First, it is important to understand what is the consumer valuation of particular tariff components and what is their impact on consumer surplus. Since mobile, fixed voice and broadband satisfy communications needs, another question is to what extent there is an additional value created when they are sold jointly, i.e., whether they are complements or substitutes. While there is clear evidence that mobile and fixed IP voice are substitutes (see for instance Grzybowski and Verboven (2014)), so far little can be said whether mobile data used on mobile handsets is a complement or a substitute to fixed broadband, which are sold jointly within quadruple play tariffs.

In this paper we estimate demand for quadruple play mobile tariffs using a database of subscribers to a single mobile operator from a single town in a European country which has full coverage with two different broadband technologies which are alternatively offered within the fixed-mobile bundle: ADSL and FTTH. In general, FTTH offers a higher speed of connection but the cost of installation is higher compared to ADSL. Based on the demand estimation we find that consumer valuation of FTTH broadband in 2013 increased over time while ADSL lost on attractiveness, which suggests that consumers increasingly care about the speed of connection offered by FTTH. The consumer surplus increased substantially with the introduction of FTTH and ongoing transition of consumers from less valued quadruple play tariffs with ADSL to more valued with FTTH.

We consider that consumers may have switching costs when choosing a new tariff. Even when consumers were free to change to a new contract, switching may involve various costs, such as search costs for a new tariff plan, transaction costs and psychological cost due to uncertainty whether a new tariff will meet the communications needs. For these reasons we may observe in

[1] According to Special Eurobarometer 414 "E-communications and Telecom Single Market Household Survey", in January 2014, 46% of European households declared that they bought two or more communication services as part of a bundled offer.

the data that consumers are biased towards using their current mobile plan. We find that there are substantial switching costs between tariffs which other things being equal greatly reduce consumer surplus.

We also find that mobile data is complementary to fixed broadband access. Mobile Internet access became possible since the introduction of 3G technology and the usage of mobile data is on rise with ongoing deployment of 4G LTE technology. However, there are bandwidth constraints of mobile networks which do not allow offering unlimited data volume within mobile tariff plans, which is nowadays a standard for fixed broadband offers. Consumers can therefore use mobile data to sample online content such as a movie and then they can complete online activity using fixed broadband at home, which has no download limit and is cheaper. Thus, fixed broadband services provide additional value to mobile data services. Consumers who get fixed broadband access value more having mobile data and vice versa.

On the other, we find that mobile voice usage is a substitute to fixed broadband access and consumers reduce their voice consumption once they get broadband connection. Because of the nature of voice calls, consumers have to choose to make a phone call using either mobile phone or fixed-line connection. Hence, consumers who purchase fixed broadband value mobile voice services less because they can also use fixed broadband for voice communication.

The remainder of the article is organized as follows. Section 2 discusses the relevant literature. Section 4 introduces the econometric framework. Section 5 presents the estimation results. Section 3 presents the data used in the estimation. Finally, Section 6 concludes.

2 Literature Review

There is a short but growing body of empirical studies using individual-level data on consumer behaviour in telecommunications industry. Recent papers of this kind use discrete choice models to analyze consumer decisions to estimate price elasticities, define relevant markets, simulate mergers, estimate switching costs or measure willingness to pay.

Among studies estimating price elasticities of demand in telecommunications industry, Ben-

Akiva et al. (1987) use data from US households and a nested logit model to analyze the choices of local telephone tariff plans. They estimate price elasticities of demand for each local service option, the number of calls, average duration, revenues with respect to the fixed monthly charges and the usage charges for calling under each option. In another paper, Pereira and Ribeiro (2011) estimate demand elasticities for broadband Internet access using Portuguese household survey data and mixed logit model. They use elasticity estimates to simulate the price effect of a structural separation between incumbent DSL broadband access to the Internet and cable broadband access to the Internet. Their results indicate that the structural separation would lead to substantial price reductions. Grzybowski et al. (2013) estimate mixed logit model for choices of broadband technologies in Slovakia and use the estimates of price elasticities to conclude on market definition. They find that demand for Internet access is highly price sensitive and that mobile broadband should be included in the relevant product market of fixed broadband technologies.

Another stream of empirical studies focuses on the estimation of switching costs in telecommunications industry. Kim (2006) uses aggregate data on Korean mobile telephony to estimate a dynamic structural model of switching decisions between tariff plans and firms. She finds that the magnitude of switching costs varies across networks and that a change in the variety of optional plans and plan characteristics plays a role in the consumer switching decision. Grzybowski (2007) uses a mixed logit model to estimate firm-specific switching costs in mobile telephony in the UK but due to data limitations does not estimate price elasticities. He finds that both switching costs and persistent tastes lead to state-dependent choices. In another paper, Grzybowski and Pereira (2011) estimate price elasticities and switching costs using discrete choice models and consumer survey data for Portugal, also finding significant switching costs which determine market structure.

There is also a number of studies which estimate willingness to pay for product attributes using invoice data. For instance, Rosston et al. (2010) use US nationwide stated-preferences survey data from December 2009 to January 2010 to estimate demand for Internet services.

They find that US household is willing to pay $45 for an improvement in speed from slow to fast, and $48 for an improvement in speed from slow to very fast. These results suggest that very fast Internet service is not worth much more to a household than fast service. In another study, Dippon (2011) uses a stated-preference survey to analyze demand determinants for mobile service bundles in the US. He finds that when selecting mobile service consumers trade off between different attributes of the offer, such as terminal price, monthly fee, monthly voice minutes and data volume included in the offer, mobile upload and download speeds, SMS prices, the type of mobile terminal offered and the length of the term contract.

There is also a short but growing body of empirical literature on bundling. Byzalov (2010) uses consumer-level data to analyze the welfare impact of various restrictions to bundling of channels for the cable television industry in the US. He finds that consumers do not gain much from unbundling, while cable networks would lose many subscribers reducing their revenues. Crawford and Yurukoglu (2012) use firm-level data to estimate the welfare effects of unbundling in the retail cable television industry in the US. They find that unbundling channels would increase input costs and consequently prices paid by consumers thus offsetting consumer surplus benefits from purchasing individual channels. Pereira et al. (2013) use consumer-level data for Portugal to analyze whether bundles of subscription television, fixed broadband and fixed voice are a relevant product market in the sense of competition policy. In another paper, Macieira et al. (2013) also use Portuguese consumer-level data where consumers choose assortments of different types of telecommunications products to analyze firms' incentives to bundle and tie in the telecommunications industry.

3 The Data

Internet access in the EU are provided by means of different mobile and fixed broadband technologies. Mobile broadband services are provided by mobile operators which developed 3G or 4G mobile networks on country's territory, or eventually by Mobile Virtual Network Operators (MVNOs) which do not have own mobile network but act as re-sellers. Mobile broadband can

be used on a computer or mobile device via a SIM card. Alternatively, consumers may purchase mobile voice services including certain amount of mobile data to be used on a mobile phone. Fixed broadband technologies include Digital Subscriber Line (DSL), fibre to the home (commonly referred to as FTTH), cable modem (CATV) and Fixed Wireless Access (or briefly WiFi).[2]

Traditionally, the telecommunications incumbents in European Union offered broadband access using DSL. Also, new entrants may offer DSL services using incumbent's infrastructure via local loop unbundling (LLU), which is the regulatory process of allowing multiple telecommunications operators to use connections from the telephone exchange to the customer's premises. Alternatively, the entrants may invest in developing own infrastructure, which is usually based on other technologies than copper-based DSL, such as FTTH, cable modem or WiFi. The incumbents also invest in developing alternative fixed broadband infrastructure, which offers higher speed of connection such as FTTH. Moreover, in most of the EU countries fixed-line incumbent is active in the provision of mobile services and offers mobile broadband.

The question we ask in this paper is how consumers choose between different mobile tariffs, whether they bundle mobile services with fixed broadband from the same provider. We use a database of subscribers to a single mobile operator in a European country which also provides fixed broadband services via both DSL and FTTH technologies. Since the nationwide coverage with ADSL in the European country considered was high but the FTTH was not deployed yet in many areas, we focus on a particular area, in which all residents have access to both ADSL and FTTH broadband technologies. Consequently, the share of quadruple play mobile users with FTTH in this area is higher than in the rest of the country. The sample is therefore not representative for the whole country but if there was full coverage with FTTH nationwide, the

[2]DSL converts the standard copper telephone line into a high speed digital line by transmitting data at higher frequencies than those used for voice. FTTH is a fiber optic cable rolled out up to home of the consumer which in general can carry data, voice and video at a higher speed than DSL. Cable modem uses access lines for cable television and in general also offers higher speed than DSL. WiFi uses 2.4 GHz UHF radio waves to connect to the fixed internet access point.

share of quadruple play users with FTTH should be comparable.

The sample also has the following limitations due to the fact that it comes from a single mobile operator which also offers fixed broadband services. First, consumers can choose between using mobile services from a given operator or switch to alternative mobile operators. We only observe that consumers are leaving but since in general consumers do not give up mobile services completely, we do not know to which mobile operator they switch. When leaving to another provider they may opt for alternative mobile service only, for a bundle of mobile and fixed broadband if such bundle is offered by the alternative provider or combine separate offers of mobile and fixed broadband services available on the market. Second, when choosing mobile services from our operator, consumers may opt for a bundle with DSL or FTTH broadband access (quadruple play tariff). But they may also use fixed broadband from our or alternative provider on a separate contract, which we do not observe in the data. Such consumers appear in the data as users of mobile services only. We therefore observe a smaller number of mobile users with ADSL and FTTH services than in reality, which will underestimate the value of ADSL and FTTH to consumers. Finally, our database includes only consumers who use contract tariffs because there is no historical information on prepaid consumers.

The critical part of discrete choice modelling is the definition of choice set for each consumer. We merge together two datasets to construct the choice sets: (i) monthly billing database including information about the tariff used by each consumer in the last 12 months before December 2013; and (ii) database on the characteristics of mobile tariffs.

The tariffs database includes on monthly basis all the tariffs which were owned by at least one consumer in the sample database in a given month. The newly purchased tariffs in a given month are available to all the consumers. Consumers used also old tariffs which are not available to others. The information on attributes of these tariffs was collected from commercial catalogues of the company. In general, three types of offers can be distinguished. The first type of offers are targeted at users of a mobile telephone for communication via phone calls, SMS and, in the case of some of the tariffs, via mobile data. The second type of offers, apart from mobile services,

includes fixed Internet access via ADSL or FTTH. The third type of offers are targeted at users of a tablet or computer, provide data services only, which are not considered in this analysis.

The most important attributes of tariffs are: (i) list price per month; (ii) length of commitment; (iii) whether a telephone subsidy is offered or SIM card only without subsidy; (iv) whether voice minutes are unlimited and if not what is the volume of minutes included in the list price; (v) the volume of mobile data in GBs included in the offer; and (vi) fixed access to Internet via DSL or FTTH. We construct a set of dummy variables for discrete tariff characteristics and use continuous variables otherwise. Table (1) shows summary statistics for 782 tariffs which are used by the consumers in the sample in the period considered.

The choice set is constructed in the following way. 'Old' consumer, who already were in the database before the first period, can choose to: (i) keep 'old' tariff; (ii) switch to a new tariff from the list of offers which is available in a given month; (iii) leave for another operator. New consumers in the first period do not have option (i) to keep old tariff in the choice set. Consequently, the choice set is different for most consumers because of the 'old' tariff. The utility which consumer derives from these offers depends on the tariff attributes including list price.

Each consumer can therefore; (i) stick to her current plan and avoid switching costs; (ii) leave for another operator or stop using the product for external reasons bearing some switching costs; (iii) migrate to a new plan within the same operator, in which case there are also some switching costs to bear. Switching costs cause an inertia towards keeping current plan even though alternative tariffs may be more attractive in terms of characteristics and prices. In the case a consumer decides to migrate from her current plan to a new one, the utility gain must compensate the disutility associated with switching costs, and similarly when a consumer chooses to leave for another operator. To account for this we define two switching costs variables in the following way. For switching between tariffs, the switching costs dummy takes value of zero if the consumer considers the choice of the same tariff as in the previous month, and one for all other alternative tariffs. The switching dummy is interpreted as a disutility from switching

to an alternative tariff. The switching costs dummy for leaving the operator takes value of zero for the choices of all tariffs, including the one selected before, and one for the choice of outside option which is leaving the operator.

Such definition of switching variables may cause identification problem. In the case of the choice of the outside option the switching dummy represents a combination of disutility resulting from switching and of utility which a consumer gets from this option. The utility may be for instance a lower price or handset subsidy offered by alternative operators. Hence, the interpretation of this dummy as purely switching costs is not appropriate. In the case of switching to alternative tariffs, since there are no tariff dummies used in the estimation, switching costs dummy may also include the utility from these alternative tariffs. However, since the tariff attributes which we use in the estimation should fully represent the utility of the tariff, the coefficient on the switching dummy can be interpreted as switching cost.

Lack of tariff dummies nevertheless causes a potential identification problem. Following Heckman (1981) consumer behaviour may be state dependent because of true and spurious factors, where true state dependency is a consequence of all observable factors, including switching costs and spurious state dependency results from persistent heterogeneity in the preferences for brands. Consumers may continue using the same tariff because it better fits their individual tastes. To account for spurious state dependence we should including random coefficients on tariff dummies, which as discussed above is not possible because of a large number of 'old' tariffs used by consumers. When spurious state dependency is ignored, the parameters representing switching costs may overestimated, i.e., state dependency in choices of tariffs appears to be only due to switching costs.

The consumer database includes information on the tariff which was used by the consumer in each month in the data and the length of the remaining commitment period in months, which may influence the ability of the consumer to switch tariff or to leave the operator. In general, consumers can freely switch tariffs during commitment period with the exception of switching to web only offers without commitment. We control for a different level of switching

costs to web only tariffs using an additional dummy variables, which takes value of one when a consumer considers choosing web only tariff and currently uses a tariff with commitment, and zero otherwise. Apart from that consumers who did not have FTTH before may have higher switching costs because a visit by a technician is needed to setup the connection which requires making an appointment. However, as discussed earlier, some consumers in our database may have FTTH connection on a separate contract and switch to fixed-mobile bundle with FTTH, in which case they do not need installation. We do not observe such cases which may bias downwards the estimate of switching costs to fixed-mobile bundles with FTTH.

The starting number of individuals in the database is 6,022 consumers from a single town. The final sample used in the estimation is 4,446. We dropped from the sample consumers who use very old tariffs for which we lack trustable information on prices and characteristics. These consumers have presumably low propensity to switch tariffs or leave the operator. We may therefore underestimate the magnitude of switching costs.

There are no consumer demographics used in the estimation because the only data collected by the operator is location, age and gender of the person which has the contract. Due to data protection issues our dataset does not include such information.

4 Econometric Model

A discrete choice framework is commonly used to analyze choices of telecommunications products including choices of tariff plans. In discrete choice models each individual chooses between a set of discrete alternatives with preferences depending on his characteristics and product attributes, and selects the one which maximizes his utility.

The first step in discrete choice modelling is to define an exhaustive and mutually exclusive choice set and consumer's decision process. We assume that a consumer chooses one among all the tariffs which are offered by the operator each month, including the tariff which he used in the previous period but may not be available to others. There are between 26 and 41 different

tariffs available to consumers each month in the time period considered.[3] Therefore, in addition to information on tariff which is used by the individual, we also need information on the price and characteristics of all the tariffs which are included in the choice set.

4.1 Utility of Mobile Tariff

We use a standard linear utility specification for individuals $i = 1, ..., N$ over the different tariffs $j = 1, ..., J$. Utility depends on tariff characteristics and on the observable and unobservable individual characteristics. The richness of data allows us to account for heterogeneity in preferences of different tariff attributes and price by means of random coefficients estimation. The utility of individual i for tariff j in month t be given by:

$$U_{ijt} = x'_{jt}\beta_i - \alpha_i p_{jt} + s'_{ijkt}\gamma_i + \epsilon_{ijt} = V_{ijt} + \epsilon_{ijt}. \tag{1}$$

where the price of tariff is denoted by p_{jt}, and α_i is the individual-specific valuation of price. Note that each consumer faces the same list prices of tariffs which are independent on usage. All tariffs include a certain volume of free minutes and data. The individual-specific valuations of tariff attributes are denoted by β_i and the vector x'_{jt} includes the following variables: (i) a dummy for ADSL broadband; (ii) a dummy for FTTH broadband; (iii) a dummy for telephone subsidy; (iv) a dummy for web only offer without commitment; (v) a dummy for unlimited voice minutes; (vi) mobile data included in the offer; (vii) voice minutes included in the offer in case the voice usage is not unlimited.

In addition, we include interaction terms of a dummy for broadband access via ADSL or FTTH with a dummy for unlimited voice minutes, as well as with variables for mobile data and voice minutes included in the offer. The purpose of these interactions is to capture potential substitution or complementarity between usage of mobile data and voice minutes and fixed broadband.

[3]Since consumers in reality may not be aware of all the tariffs which are in offer, an alternative approach is to limit the choice set of each consumer by drawing randomly a fixed number of tariffs from all which are available in the current month.

The vector of switching dummies is denoted by s'_{ijkt} and coefficients γ_i represents disutility from switching which approximates switching costs. We consider two types of switching dummies. The first one takes value of zero if consumer i in the previous month $t-1$ used alternative $k = j$ and one otherwise when $k \neq j$. The second one takes value zero for the choice of any tariff and one for the choice of outside option, which is to leave the operator. This is the disutility from leaving the provider. In addition, we allow switching costs to vary depending on whether consumers consider switching to quadruple play tariffs which include FTTH or low-priced web only tariffs. Switching costs are also allowed to vary depending on whether the consumer is still under commitment and in dependence on the number of months left in commitment. We discuss the identification of switching costs below.

Finally, ϵ_{ijt} is individual-specific valuation for tariff j at time t, i.e. the "logit error term". It is assumed identically and independently distributed across tariffs according to type I extreme value distribution.

The vector of coefficients $\theta_i = (\alpha_i, \beta_i, \gamma_i)'$ depends on unobserved heterogeneity. More specifically, we can write: $\theta_i = (\alpha, \beta, \gamma)' + \nu_i \sim N(0, \Sigma)$, where (α, β, γ) refers to a vector of mean valuations, ν_i is a randomly drawn vector from joint normal distribution with Σ represents a diagonal matrix with the diagonal elements being standard deviations around the mean valuations. In our empirical analysis, there are no observable individual characteristics which influence choices or valuations of tariff attributes because such information is limited and confidential.

4.2 Choice Probabilities

An individual i chooses a tariff j in month t if this tariff maximizes the utility among all available alternatives, i.e., if $U_{ijt} = \max_{n \in C_{it}} U_{int}$, where C_i is individual i's available choice set. Hence, the probability that individual i with given random coefficients β_i, α_i and γ_i makes a sequence

of tariff choices $j = \{j_1, j_2, ..., j_T\}$ is given by:

$$\begin{aligned} l_{ij}(\theta_i) &= \prod_{t=1}^{T} \Pr\left(U_{ij_t t} = \max_{n \in C_{it}} U_{int}\right) \\ &= \prod_{t=1}^{T} \frac{\exp\left(x'_{j_t t}\beta_i - \alpha_i p_{j_t t} + s'_{ij_t kt}\gamma_i\right)}{\sum_{n \in C_{it}} \exp\left(x'_{nt}\beta_i - \alpha_i p_{nt} + s'_{inkt}\gamma_i\right)} \end{aligned}$$

where the second line follows from the distributional assumptions of the logit error term ϵ_{ijt}.

In the special case when Σ is a matrix of zeros, there is no unobserved individual heterogeneity and we obtain the conditional logit model. More generally, we have a mixed logit model, which allows for unobserved heterogeneity among individuals and requires integration of the conditional choice probability $l_{ij}(\theta_i)$ over the joint distribution of θ_i:

$$P_{ij}(\theta, \Sigma) = \int_{\theta_i} l_{ij}(\theta_i) f(\theta_i) d\theta_i. \tag{2}$$

where θ and Σ are the parameters to be estimated. This is mixed logit or random coefficients logit choice probability.

4.3 Estimation Strategy

The probability that each individual in the sample chooses the sequence of alternatives as observed can be written as the log-likelihood function:

$$\mathcal{L}(\theta, \Sigma) = \sum_{i}^{N} \log(P_{ij}(\theta, \Sigma)). \tag{3}$$

To approximate the integral entering the choice probabilities $P_{ij}(\theta, \Sigma)$ in (2), we use a simulation method, where following Train (2003) we take R draws for ν from the joint normal distribution to obtain the average choice probability per individual:

$$\widehat{P}_{ij}(\theta, \Sigma) = \frac{1}{R} \sum_{r=1}^{R} \prod_{t=1}^{T} \frac{\exp\left(x'_{j_t t}(\beta + \sigma_\beta \nu_i^r) - (\alpha + \sigma_\alpha \nu_i^r) p_{j_t t} + s'_{ij_t kt}(\gamma + \sigma_\gamma \nu_i^r)\right)}{\sum_{n \in C_{it}} \exp\left(x'_{nt}(\beta + \sigma_\beta \nu_i^r) - (\alpha + \sigma_\alpha \nu_i^r) p_{nt} + s'_{inkt}(\gamma + \sigma_\gamma \nu_i^r)\right)}. \tag{4}$$

In the special case of no unobserved individual heterogeneity, this reduces to the multinomial choice probability:

$$\widehat{P}_{ij}(\theta, \Sigma) = \sum_{t=1}^{T} \frac{\exp\left(x'_{j_t t}\beta - \alpha p_{j_t t} + s'_{ij_t kt}\gamma\right)}{\sum_{n \in C_{it}} \exp\left(x'_{nt}\beta - \alpha p_{nt} + s'_{inkt}\gamma\right)}.$$

The maximum simulated likelihood estimator are parameters θ and Σ which maximizes the likelihood function $\mathcal{L}$ given by (3), after substituting (4).[4]

4.4 Consumer Surplus

We use the estimates to calculate changes in consumer surplus due to policy intervention. In the discrete choice framework, the expected consumer surplus of consumer i is given by (see Small and Rosen (1981)):

$$E(CS_{it}) = \int_{\theta_i} \frac{1}{|\alpha_i|} ln\Big(\sum_j \exp(V_{ijt})\Big) d\theta_i + C_i$$

where α_i is the individual-specific price coefficient, $V_{ijt} = x'_{jt}\beta_i - \alpha_i p_{jt} + s'_{ijkt}\gamma_i$ is the observed part of the utility function and C_i is an unknown constant which represents the unmeasured level of utility. A change in consumer surplus due to policy intervention can be written as:

$$\Delta E(CS_{it}) = \int_{\theta_i} \frac{1}{|\alpha_i|} \Big| ln\Big(\sum_j \exp(V^1_{ijt})\Big) - ln\Big(\sum_j \exp(V^0_{ijt})\Big) \Big| d\theta_i \tag{5}$$

where V^1_{ijt} denotes the utility after and V^0_{ijt} before policy intervention.

5 Estimation Results

We estimate the model using multinomial logit without unobserved heterogeneity and mixed logit with random variables on selected tariff attributes, which allow for heterogeneity in consumer valuation of tariff attributes. The estimation results are shown in Tables (2) and (3) respectively. In both models the estimates of the coefficients on price is negative and highly significant as anticipated. The estimates of the coefficients for all attributes of a mobile plan are positive and highly significant. These attributes therefore significantly increase consumer valuation of the tariff. For instance, web only tariffs are positively valued by consumers, which may be because of lack of commitment or other advantages. Consumers have also positive valuation of tariffs with handset subsidy and of quadruple play tariffs with FTTH and ADSL fixed broadband access.

[4]The algorithm for estimating mixed logit model is explained in detail in Train (2003).

There is a significant heterogeneity in consumer preferences for tariff attributes. For instance, consumers differ with respect to price sensitivity since the standard deviation on price coefficient is significant. They also differ with respect to valuation of handset subsidy, web only tariffs, mobile data and voice volume included in the offer. The perception of substitution between unlimited voice minutes and fixed broadband access also varies by consumers and they have different switching costs between tariffs.

We can use the estimates to compute the valuation of Internet access via ADSL and FTTH in the fixed-mobile bundle and analyze how it changes over time. This is an important issue because the governments in the European Union try to stimulate deployment of high speed Internet access via FTTH. There would be little justification for this objective if consumers were indifferent between ADSL and FTTH access. We estimate separate dummy variables for the inclusion of ADSL and FTTH in the fixed-mobile bundle and in addition allow these dummies to vary over time on monthly basis, which for mixed logit model is illustrated on Figure (1). The marginal value of FTTH in fixed-mobile bundles is increasing over time while the marginal value of ADSL is decreasing. In the first month in the data, FTTH was valued about 27% more than ADSL but at the end of 2013 it was valued almost three times more. This may be due to the fact that consumers increasingly care about the speed of their Internet connection because of growing range of products which require higher bandwidth such as IP TV and online video services.

We also use the mixed logit model to compute changes in consumer surplus due to the introduction of quadruple play offers with ADSL and FTTH, as shown in Table (4). The measurement of consumer surplus is important because it can help to assess the benefits of nationwide deployment of FTTH, as compared to ADSL which already has wide coverage. We use the formula (5) to calculate the difference in consumer surplus between the base case scenario which is current situation and the case in which quadruple play tariffs with FTTH and/or ADSL are withdrawn from the market, which is equivalent to an infinite price increase for the tariffs with ADSL and/or FTTH, so that there are no consumers choosing these tariffs. As shown

in Table (4), in December 2013 the consumer surplus would drop on average by about 7.4 Euros in the absence of fixed-mobile bundles with FTTH, by 1.1 Euros in the absence bundles with ADSL and by 8.8 Euros in the absence of quadruple play tariffs including any broadband access. These averages are calculated for the whole sample of consumers including those without any broadband access. For comparison we calculate the difference in consumer surplus if web only tariffs were not available to consumers. In the absence of these tariffs, in December 2013 the consumer surplus would be on average lower by 11.4 Euros. The effect of these tariffs on consumer surplus is greater because they are used by a larger number of consumers.

The results suggest that introduction of quadruple play tariffs brings significant benefits to consumers. However, as already mentioned, an important limitation of our analysis that many mobile consumers may have two independent contracts, one for mobile services and another triple play contract which includes VoIP, broadband and IP TV from the same or another provider. We do not observe in the data which consumers have separate broadband contracts. The valuation of ADSL and FTTH within fixed-mobile bundle may be therefore underestimated.

According to other estimation results consumers have a positive marginal valuation of mobile data and voice minutes included in the tariff. They also value positively tariffs with unlimited volume of minutes. We include in the model interaction terms between these tariff components to analyze how they impact consumer utility when they are offered jointly, i.e., whether there is substitution or complementarity between voice and data. The interaction of mobile data volume with unlimited calling volume is insignificant which suggests that voice calls and mobile data are independent, i.e., consumer utility does not change due to the fact that these services are offered together. This result may also imply that VoIP services which are potentially included in mobile data access (as one of Over-The-Top services) is not a substitute to mobile unlimited voice service. We also find that consumers value less unlimited calling volume when this option is part of quadruple tariff. This may be due to the fact that at home consumers can use fixed Internet access to communicate instead of free mobile calls. On the other hand, we find that for quadruple play subscribers mobile data is complementary to fixed broadband access, which

suggests that consumers use Internet access via mobile data to sample online content but they complete their online activity using fixed Internet access at home.

Moreover, we find that there are significant switching costs between tariffs because of which consumers are not able to switch to a tariff which is better suited to their usage behaviour. The estimation results suggest that switching costs are higher for consumers who still have contract commitment and depend positively on the number of months left with commitment, i.e., the longer is the time of commitment left the higher are switching costs. Switching costs are also higher for switching to web only tariffs because in this case consumers under commitment have to pay for switching. Moreover, switching to quadruple play tariffs with FTTH is also more costly because consumers may need to fix an appointment with a technician to initiate the connection. Our results suggest that switching costs are to a large extent caused by consumers' inertia rather than result from contractual commitment.

We also find that it is costly for consumers to leave the operator even though, as discussed above, the coefficient on leaving dummy cannot be interpreted strictly as switching cost because of lack of information on where these consumers go. To understand the impact of switching costs on consumer surplus we calculate the difference between current situation and a hypothetical situation in which switching costs between tariffs are set to zero. As shown in Table (4) in the absence of switching costs between tariffs consumer surplus would be on average higher by about 47 Euros in December 2013. There are therefore substantial switching costs which constrain consumer ability to choose optimal tariff. However, as already mentioned above, switching costs may be overestimate because we do not control for spurious state dependency which is related to consumer preferences for a particular tariff.

6 Conclusion

There is a growing popularity of quadruple play tariffs which include mobile voice and data, fixed IP voice, fixed broadband and IP TV. In this paper we estimate demand for quadruple play tariffs using a database of subscribers to a single mobile operator from a single town in an

European country which has full coverage with both ADSL and FTTH broadband. Based on the demand estimates we find that consumer valuation of FTTH broadband in 2013 increased over time while ADSL lost on attractiveness, which suggests that consumers increasingly care about the speed of connection offered by FTTH. The consumer surplus increased substantially due to the introduction of quadruple play tariffs and ongoing transition of consumers from less valued quadruple play tariffs with ADSL to more valued with FTTH. This is an important finding for the policy makers who try to stimulate deployment of high speed Internet access via FTTH. If consumers were indifferent between ADSL and FTTH access this policy would have no justification.

Since tariff components mobile voice and data, fixed voice IP and fixed broadband all satisfy communications needs, pricing of these components depends on whether they are substitutes or complements. We find that for quadruple play subscribers mobile data is complementary to fixed broadband access, which suggests that these consumers use Internet access via mobile data to sample online content but they complete their online activity using fixed Internet access at home, which has no download limit and is cheaper. Thus, fixed broadband services provides additional value to mobile data services. On the other hand, mobile voice usage is a substitute to fixed broadband access and consumers reduce their voice consumption once they get broadband connection.

Finally, we find that there are substantial switching costs between tariffs which restrict the ability of consumers to choose a tariff which is best-suiting to their communications needs. Switching costs are higher for consumers with contractual commitment but our results suggest that they are to a large extent caused by consumers' inertia towards the same tariff.

Bibliography

Ben-Akiva, M., McFadden, D.L. and K.E. Train, 1987. "The Demand for Local Telephone Service: A Fully Discrete Model of Residential Calling Patterns and Service Choices," *Rand Journal of Economics*, 18(1), pp.109-23.

Byzalov, D. (2010). "Unbundling Cable Television: An Empirical Investigation," mimeo.

Crawford, G. and A.Yurukoglu (2012). "The Welfare Effects of Bundling in Multichannel Television Markets," *American Economic Review*, 102(2),pp. 643-85.

Dippon, C.M., 2012 "Consumer Demand for Mobile Phone Service in the US: An Examination beyond the Mobile Phone."

Hole, A.R., 2007. "Fitting mixed logit models by using maximum simulated likelihood."The Stata Journal 7: 388-401.

Grzybowski, L., 2007. "Estimating Switching Costs in Mobile Telephony in the UK," *Journal of Industry, Competition and Trade*, 8(2), pp.113–132.

Grzybowski, L. and P. Pereira, 2011. "Subscription Choices and Switching Costs in Mobile Telephony," *Review of Industrial Organization*, 38, pp.23–42.

Grzybowski, L., Nitsche, R., Verboven, F. and L. Wiethaus, 2013. "Market Definition for Broadband internet in Slovakia – Are Fixed and Mobile Technologies in the Same Market?" mimeo.

Grzybowski, L. and F. Verboven, 2013. "Substitution between Fixed-line and Mobile Access: the Role of Complementarities," *NET Institute Working Paper # 13-09*.

Heckman, J., 1981. "Statistical Models for Discrete Panel Data," C.F. Manski and D. McFadden, eds. *Structural Analysis of Discrete Data with Econometric Applications*, Cambridge, MA: The MIT Press, pp.179-195.

Kim, J., 2006. "Consumers' Dynamic Switching Decisions in the Cellular Service Industry," *NET Institute Working Paper # 06-24*.

Macieira, J., Pereira, P. and J. Vareda, 2013. "Bundling Incentives in Markets with Product Complementarities: The Case of Triple-Play," NET Institute Working Paper #13-15.

Pereira, P. and T. Ribeiro, 2011. "The impact on broadband access to the Internet of the dual ownership of telephone and cable networks," *International Journal of Industrial Organization*, 29, pp.283-293.

Pereira, P., Ribeiro, T. and J. Vareda, 2013. "Delineating Markets for Bundles with Consumer Level Data: The Case of Triple-Play," *International Journal of Industrial Organization*, 31, pp.760-773.

Rosston, G., Savage, S.J., and D.M. Waldman, 2010. "Household Demand for Broadband Internet Service, " *Federal Communications Commission*.

Small, K.A. and H.S. Rosen, 1981. "Applied Welfare Economics with Discrete Choice Models," *Econometrica*, 49, pp.105–30.

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

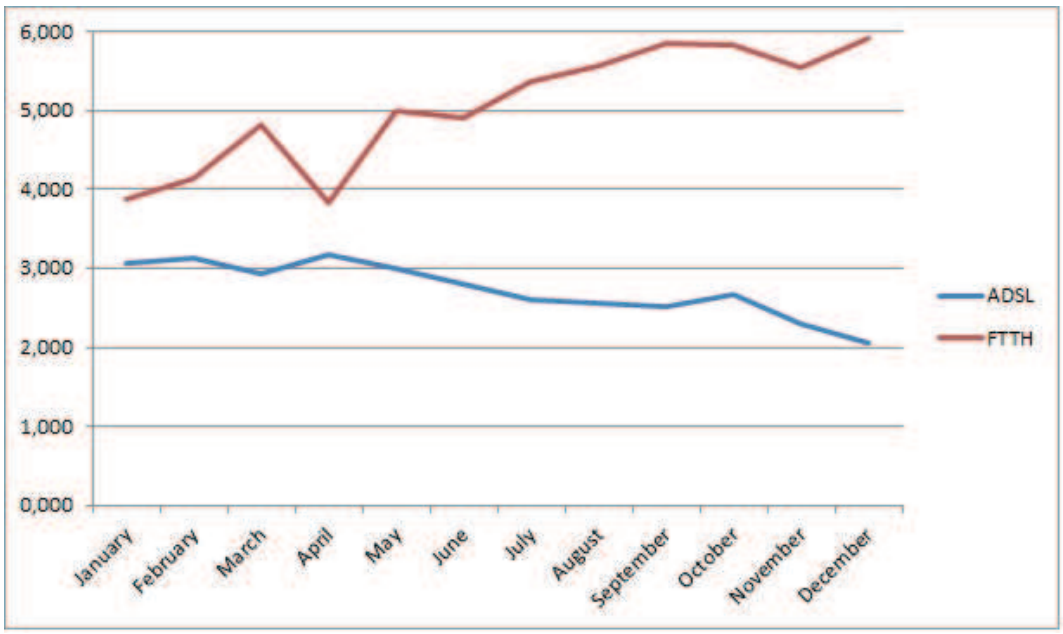
Appendix

Table 1: Summary statistics of mobile tariffs

Variable	Obs	Mean	Std.	Min	Max
price	782	41.58	24.17	4.90	100.99
phone subsidy	782	0.82	0.39	0	1
adsl	782	0.16	0.37	0	1
ftth	782	0.11	0.31	0	1
web only tariffs	782	0.12	0.33	0	1
mobile data (GB)	782	1.22	1.37	0	7
unlimited	782	0.50	0.50	0	1
voice limited (mn)	782	50.34	58.74	0	300

In total there are 782 tariffs used in the estimation. There are between 26 and 41 different tariffs available to consumers each month. Consumers used also older tariffs which may not be available to others.

Figure 1: Valuation of quadruple play ADSL and FTTH (based on mixed logit regression)



Changes over time in the marginal value of ADSL and FTTH in the fixed-mobile bundle.

Table 2: Multinomial logit estimates

Variables	Estimates	Months	ADSL	FTTH	Outside good
Price	-0.080***	January	2.510***	3.404***	-5.864***
	(0.002)		(0.213)	(0.330)	(0.264)
Handset subsidy	1.129***	February	0.061	0.174	-0.484
	(0.059)		(0.212)	(0.342)	(0.407)
Web only tariffs dummy	2.643***	March	-0.174	0.715**	-0.812*
	(0.128)		(0.214)	(0.325)	(0.457)
Mobile data	0.300***	April	0.044	-0.292	-0.565
	(0.041)		(0.198)	(0.349)	(0.437)
Unlimited voice dummy	2.996***	May	-0.113	0.904***	-1.761**
	(0.072)		(0.197)	(0.295)	(0.752)
Voice volume	0.011***	June	-0.345*	0.748***	1.286***
	(0.000)		(0.191)	(0.282)	(0.300)
Mobile data + unlimited	0.043	July	-0.560***	1.175***	1.605***
	(0.041)		(0.189)	(0.269)	(0.291)
Mobile data + broadband	0.147***	August	-0.547***	1.278***	1.429***
	(0.029)		(0.197)	(0.275)	(0.301)
Unlimited voice + broadband	-0.937***	September	-0.583***	1.569***	1.906***
	(0.156)		(0.194)	(0.270)	(0.288)
Voice volume + broadband	-0.002	October	-0.443**	1.524***	2.045***
	(0.002)		(0.210)	(0.273)	(0.288)
Switching tariff	-7.122***	November	-0.817***	1.243***	1.851***
	(0.049)		(0.200)	(0.272)	(0.292)
Switching tariff with contract	-0.376***	December	-1.047***	1.600***	2.022***
	(0.063)		(0.203)	(0.265)	(0.290)
Switching tariff with time left	-0.060***				
	(0.003)				
Switching to web only tariffs	-3.282***				
	(0.131)				
Switching to tariffs with FTTH	-1.330***				
	(0.178)				
Leaving - with contract	-1.087***				
	(0.162)				
Leaving - time left	0.019				
	(0.012)				
LL	-24,009				
Observations	1,861,811				

Dummy variables for the inclusion of ADSL and FTTH in the tariff are interacted with monthly dummies. The utility of the outside option (leaving the operator) is also allowed to vary on month basis.

Table 3: Mixed logit estimates

Variables	Mean	STD	Months	ADSL	STD	FTTH	STD	Outside good	STD
Price	-0.099***	0.012***	January	3.067***	-0.023	3.887***	-0.053	-7.015***	1.104***
	(0.002)	(0.002)		(0.238)	(0.102)	(0.355)	(0.196)	(0.329)	(0.249)
Handset subsidy	1.851***	-1.083***	February	0.075		0.251		-0.473	
	(0.182)	(0.233)		(0.211)		(0.341)		(0.425)	
Web only tariffs dummy	3.370***	-0.707*	March	-0.127		0.931***		-0.792*	
	(0.226)	(0.421)		(0.216)		(0.328)		(0.478)	
Mobile data	0.487***	0.151***	April	0.102		-0.050		-0.373	
	(0.053)	(0.036)		(0.200)		(0.347)		(0.452)	
Unlimited voice dummy	3.493***	-0.046	May	-0.062		1.108***		-1.578**	
	(0.091)	(0.110)		(0.199)		(0.298)		(0.766)	
Voice volume	0.013***	0.006***	June	-0.263		1.030***		1.675***	
	(0.001)	(0.000)		(0.196)		(0.286)		(0.321)	
Mobile data + unlimited	-0.096*	0.059	July	-0.471**		1.474***		2.081***	
	(0.054)	(0.059)		(0.193)		(0.274)		(0.312)	
Mobile data + broadband	0.169***	0.065	August	-0.504**		1.673***		1.939***	
	(0.039)	(0.105)		(0.204)		(0.282)		(0.322)	
Unlimited voice + broadband	-1.361***	-0.708***	September	-0.549***		1.967***		2.475***	
	(0.203)	(0.162)		(0.201)		(0.277)		(0.311)	
Voice volume + broadband	-0.003	-0.001	October	-0.392*		1.952***		2.698***	
	(0.002)	(0.001)		(0.221)		(0.281)		(0.312)	
Switching tariff	-7.368***	0.430***	November	-0.764***		1.663***		2.535***	
	(0.058)	(0.053)		(0.210)		(0.280)		(0.318)	
Switching tariff with contract	-0.471***		December	-1.016***		2.041***		2.705***	
	(0.070)			(0.213)		(0.274)		(0.317)	
Switching tariff with time left	-0.070***								
	(0.004)								
Switching to web only tariffs	-4.157***								
	(0.225)								
Switching to tariffs with FTTH	-1.323***								
	(0.189)								
Leaving - with contract	-1.324***								
	(0.186)								
Leaving - time left	0.014								
	(0.013)								
LL	-23,826								
Observations	1,861,811								

Dummy variables for the inclusion of ADSL and FTTH in the tariff are interacted with monthly dummies. The utility of the outside option (leaving the operator) is also allowed to vary on month basis.

Table 4: Difference in average consumer surplus (in Euros)

Month	No FTTH	No ADSL	No ADSL & FTTH	No web only	No switching costs
January	-0.6	-4.6	-5.3	-9.0	54.0
February	-0.8	-4.4	-5.3	-9.7	53.0
March	-1.1	-4.1	-5.4	-10.2	52.7
April	-0.9	-3.5	-4.5	-9.5	52.7
May	-1.3	-3.4	-4.8	-10.4	52.1
June	-1.7	-2.9	-4.8	-10.1	50.9
July	-2.4	-2.3	-4.9	-10.3	52.2
August	-3.4	-2.1	-5.7	-11.0	50.5
September	-4.3	-1.9	-6.4	-10.7	49.0
October	-5.6	-1.9	-7.8	-11.3	46.1
November	-6.1	-1.5	-7.8	-11.4	47.5
December	-7.4	-1.1	-8.8	-11.4	47.1

Difference between current base case and counterfactual situation: (1) without quadruple play offers with FTTH; (2) without quadruple play offers with ADSL; (3) without quadruple play offers with FTTH and ADSL; (4) without web only offers; (5) with zero switching costs.