# 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 mixed logit demand estimation we find that consumer valuation of FTTH broadband in 2013 increased over time, while ADSL lost attractiveness relative to FTTH and in absolute terms, which suggests that consumers increasingly care about the speed of connection offered by FTTH. Consumer surplus increased substantially due to ongoing transition of consumers from less valued quadruple play tariffs with ADSL to more valued ones 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 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 a broadband connection. We also find that

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there are substantial switching costs between tariffs which, other things being equal, greatly decrease consumer surplus.

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# 1 Introduction

In recent years many telecommunications operators in Europe have 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 the consumer valuation of particular tariff components and their impact on consumer surplus. Since communications needs may be satisfied by voice and broadband delivered on mobile or fixed networks, another question is to what extent there is an additional value created when these services 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 as to whether mobile data used on mobile handsets is a complement or a substitute to fixed broadband, with both sold together in 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 offered as alternatives within the fixed-mobile bundle: asymmetric digital subscriber line (ADSL) and fibre to the home (FTTH).[2] In general, FTTH offers a higher speed of connection but the cost of installation at home is also higher compared to ADSL. Based on the mixed logit demand estimation we find that consumer valuation of FTTH broadband in 2013 increased over time, while ADSL lost attractiveness, which suggests that consumers increasingly care about the speed of connection offered by FTTH. Consumer surplus increased substantially with the introduction of FTTH and the ongoing transition of

[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.

[2] ADSL converts 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 the home of the consumer which in general can carry data, voice and video at a higher speed than DSL.

consumers from less valued quadruple play tariffs with ADSL to more valued ones with FTTH.

We consider that consumers may have switching costs when choosing a new tariff. Even if consumers are not limited by a contractual commitment, switching may involve various costs, such as search costs for a new tariff plan, transaction costs and psychological cost due to uncertainty whether the new tariff will meet their communications needs. For these reasons we may observe that consumers are biased towards using their current mobile plan. Indeed, 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 with the introduction of third generation (3G) technology and usage of mobile data is on the rise with the ongoing deployment of 4G LTE technology.[3] However, there are bandwidth constraints with mobile networks which do not allow unlimited data volumes to be offered within mobile tariff plans, which is nowadays a standard for fixed broadband offers. Consumers can therefore use mobile data to sample online content and then they can complete online activity using fixed broadband at home, with no download limit. Thus, fixed broadband services provide a complementary value to mobile data services. Consumers who get fixed broadband access value having mobile data more and vice versa.

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

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

[3]Long-Term Evolution (LTE), which is commonly marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals.

## 2 Literature Review

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

Among studies estimating price elasticities of demand in the 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 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 the 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 the 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 the 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 a 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 services, 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 contract.

There is also a small 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 context 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

Our analysis is based on the estimation of discrete choice models for individual-level information. There are two databases which we use to conduct this analysis. The first database consists of monthly choices of mobile telecommunications tariffs between January and December 2013 by all contract subscribers to a single operator who live in a single town in a European country. We focus on this town because of its full coverage with two fixed broadband technologies: ADSL and FTTH, which can be chosen by these subscribers as part of a quadruple play tariff. Due to confidentiality reasons this database does not include any individual-specific data, except for information about the remaining length of commitment. The second database includes the characteristics of all tariffs available to consumers in each month between January and December 2013. These two databases are merged using month as a key. The starting number of individuals in the database is 6,022 consumers. The final sample used in the estimation is 4,429. We dropped consumers from the sample who in at least one month used an old tariff, for which there was no information on characteristics.

The question asked in this paper is how consumers choose between different mobile tariffs and whether they are willing to bundle mobile services with fixed broadband from the same provider. Consumers are able to choose a fixed-mobile bundle on the condition that fixed broadband offered by their mobile operator is available at their premises. Internet access via ADSL is based on a copper network which has country-wide coverage, whereas deployment of FTTH is quite recent in the country considered and so far is available only in selected, more densely populated areas. But even in these areas some consumers may not be able to use FTTH technology if there is no physical connection from their premises to the central office.[4] In this analysis we circumvent the problem of unavailability of FTTH to consumers by focusing on a specific town in the country, in which the mobile operator considered has fully deployed FTTH technology to consumers premises. Deployment of FTTH in this town started in 2011 with the

[4]The "central office" is typically a building used to house telecommunications equipment serving a certain geographical exchange area.

objective of making it available to all households by the end of 2012. So from January 2013, the first month of our data, consumers can decide whether to bundle their mobile services with ADSL or FTTH broadband.[5]

### The Choice Set

Modelling consumer decisions by means of discrete choice requires the definition of a choice set. We construct the choice set for each month in the following way. 'Old' consumers, who were subscribers to mobile services of our operator already in the first month of the data, can choose to: (i) keep their old tariff; (ii) switch to a new tariff from the list of offers available in a given month; (iii) leave their current operators services. 'New' consumers in the first period do not have option (i) to keep the old tariff in the choice set. Consequently, the choice set is different for most 'old' consumers because of the old tariff, but is the same for all consumers who are 'new' in a given month.

Our analysis has the following limitation with respect to the choice of option (iii) due to the fact that the data comes from a single mobile operator. Leaving consumers may terminate their current contract and subscribe to a new contract with the same operator with a new mobile number, which is quite rare. But consumers may also change to a prepaid tariff with our operator, in which case they do not have monthly bills and are not visible in the database. In most cases, consumers leave for other operators choosing either mobile services only or a fixed-mobile bundle, if such a bundle is offered by the alternative operator. In the remainder of the paper we refer to all consumers choosing option (iii) as leaving consumers. Moreover, when choosing option (ii), which is a mobile service from our operator, consumers may opt for a quadruple play tariff which includes ADSL or FTTH broadband access. But they may also use fixed broadband on a separate contract from our or an alternative operator, which we do

[5]The consequence of focusing on a single town instead of using a country-wide sample is that our analysis is not representative at the country level at the current stage of deployment of FTTH. However, we may consider that it accurately reflects consumer behavior in a situation in which all consumers in the country have access to ADSL and FTTH broadband technologies offered by our mobile operator.

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 access than in reality.

We determine the set of new tariffs in each month using the subscriptions database. We consider a tariff to be new whenever in a given month there was at least one 'new' consumer who selected this tariff or at least one 'old' consumer who switched to it. Otherwise, the tariff is considered old and not available in a given month. Hence a new tariff in one month becomes an old and unavailable tariff in the next month if there are no new consumers who choose it or 'old' consumers who switch to it. The total number of unique new tariffs in the time period considered is 211. The number of completely new tariffs introduced ranges between 5 and 54 per month. The remaining tariffs to which consumers subscribe are considered to be old tariffs. There were 352 unique old tariffs in total used by consumers in our sample during 2013. Overall, the choice set of each consumer ranges between 43 and 65 tariffs depending on the month.

The utility which a consumer derives from these tariffs depends on a set of attributes including list price. The most important attributes are: (i) list price per month; (ii) length of commitment; (iii) whether a handset subsidy is offered or SIM card only without a subsidy; (iv) whether voice minutes are unlimited and, if not, what is the volume of minutes included; (v) the volume of mobile data in GBs included; and (vi) fixed access to the Internet via ADSL or FTTH broadband.

We construct a set of dummy variables for discrete tariff characteristics and otherwise use continuous variables. Table (1) shows summary statistics for new and old tariffs which are used by consumers in the sample. The average price of old and new tariffs is similar but there are more old tariffs with phone subsidy and fewer old quadruple play tariffs with ADSL, and especially with FTTH broadband. Also, new tariffs on average include unlimited phone calls and more mobile data, while old tariffs include an allowance of minutes.

In terms of popularity of tariffs, 4,429 consumers in our sample made a total of 50,964 monthly tariff choices during 2013, where the top 10 tariffs were selected by 33% of consumers,

top 20 tariffs by 46.1% and top 50 tariffs by 64.3%. In the last month of the data about 5.8% of mobile subscribers used quadruple play tariffs with ADSL and about 14.8% used tariffs with FTTH.

### Switching Costs

Each consumer can: (i) stick to their current tariff and avoid switching costs; (ii) migrate to a new tariff with the same operator bearing some switching costs; (iii)) stop using their contract tariff and leave for another operator, in which case there are also some switching costs to bear.

Switching costs cause an inertia towards keeping a current plan, even though alternative tariffs may be more attractive in terms of characteristics and prices. In the case where a consumer decides to migrate from their current tariff 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 types of switching costs variables in the following way. For switching between tariffs, the switching costs dummy takes a value of zero if the consumer considers choosing the same tariff as in the previous month, and one for all other alternative tariffs available in the current month. The switching dummy is interpreted as a disutility from switching to an alternative tariff. The switching costs dummy for leaving the operator takes a value of zero for all tariffs, including the one selected before, and one for the choice of an outside option, which means leaving the operator.

The lack of precise information about what consumers do when they choose the outside option, as discussed above, causes a problem with the identification of the costs of switching to the outside option. This is because the dummy variable for switching to the outside option is equivalent to a dummy variable for the valuation of the outside option. Hence, this dummy represents a combination of the disutility from switching and the utility which a consumer gets from this option. The utility may for instance be the lack of a commitment when migrating to a prepaid tariff, or a handset subsidy and lower price offered by an alternative operator. Therefore, the interpretation of this dummy as switching costs is not appropriate and instead

we call it a leaving dummy.

In the case of switching to alternative tariffs, since there are no tariff dummies used in the estimation, the switching costs dummy may also include the utility from these alternative tariffs. However, if the tariff attributes we use in the estimation fully represent the utility of the tariff, the coefficient on the switching dummy can be interpreted as switching costs.

Another problem with identification of switching costs is due to unobserved time-persistent preferences. Following Heckman (1981), consumer behavior 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 preferences for brands. Consumers may continue using the same tariff because it better fits their individual tastes. 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. We allow for unobserved time-persistent individual preferences of particular tariff characteristics by means of mixed logit estimation for panel data.

The consumer database includes information on the tariff 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 their 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 variable, which takes a value of one when a consumer considers choosing a web only tariff and currently uses a tariff with commitment, and zero otherwise. Aside from that, consumers who did not have FTTH before may have higher switching costs because a visit by a technician is needed to set up the connection. However, as discussed earlier, some consumers in our database may have an FTTH connection on a separate contract and switch to a 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 total number of tariff switches made by consumers in our sample in 2013 is 3,671 out of 50,964 monthly tariff choice observations, which represents 7.2%. There is some variation in the number of switches per month ranging between 4.7% and 10.9%. Table 2 shows the number of switchers in the database and that only 35% never switched a tariff, 50% switched once, 13% twice and 2% three times or more. These numbers indicate that switching tariffs is very common. However, we dropped consumers from the sample who in at least one month used an old tariff, information on which is missing in our tariff database. These consumers presumably have a low propensity for switching tariffs or leaving the operator. Because of this the magnitude of switching costs based on our sample may be underestimated.

# 4 Econometric Model

A discrete choice framework is commonly used to analyze choices of telecommunications products including choices of tariff plans. In a discrete choice model, each individual chooses between a set of discrete alternatives 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 the consumers decision process. We consider that a consumers choice set consists of 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. 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. There are between 43 and 65 different tariffs available to consumers each month in the time period considered.[6]

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

### 4.1 The Utility of the Mobile Tariff

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

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

where the price of tariff is denoted by $p_{jt}$, and $\alpha_i$ is the individual-specific valuation of price. Note that all consumers are presented with the same list prices of tariffs which are independent of usage. The individual-specific valuations of tariff attributes are denoted by $\beta_i$ 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 handset subsidy; (iv) a dummy for web only offer without commitment; (v) dummies for 12 and 24 month contracts; (vi) a dummy for unlimited voice minutes; (vii) mobile data included in the offer; (viii) voice minutes included in the offer if 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.

The vector of switching dummies is denoted by $s'_{ijkt}$ and coefficients $\gamma_i$ represent the disutility from switching which approximates switching costs. As discussed in the previous section, we consider two types of switching dummies. The first one takes a 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 a value of zero for the choice of any tariff and one for the choice of an 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 relation to the number of months left in the commitment. We discussed the identification of switching costs in the previous section.

Finally, $\epsilon_{ijt}$ is the individual-specific valuation for tariff $j$ at time $t$, i.e., the "logit error term". It is assumed to be identically and independently distributed over tariffs and individuals 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: $\theta_i = (\alpha, \beta, \gamma)' + \nu_i$, where $(\alpha, \beta, \gamma)$ is a vector of mean valuations and $\nu_i \sim N(0, \Sigma)$ is a randomly drawn vector from a joint normal distribution with $\Sigma$ representing 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 valuations of tariff attributes because such information is limited and confidential.

### 4.2 Choice Probabilities

An individual $i$ chooses in month $t$ a tariff $j$ with the highest utility among all the available alternatives, i.e., if $U_{ijt} = \max_{n \in C_{it}} U_{int}$, where $C_{it}$ is individual $i$'s choice set in month $t$. Hence, the probability that individual $i$ with random coefficients $\beta_i$, $\alpha_i$ and $\gamma_i$ makes a sequence of tariff choices $j = \{j_1, j_2, ..., j_T\}$ is given by:

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

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

In general, we have a mixed logit model which allows for unobserved time-persistent heterogeneity among individuals and requires integration of the conditional choice probability $l_{ij}(\theta_i)$

over the joint distribution of $\theta_i$:

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

where $\theta$ and $\Sigma$ are the parameters to be estimated. In the special case when $\Sigma$ is a matrix of zeros, there is no unobserved individual heterogeneity and we estimate the conditional logit model.

### 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 $\nu$ 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 without unobserved individual heterogeneity, this expression reduces to the multinomial choice probability:

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

The maximum simulated likelihood estimator are the values of parameters $\theta$ and $\Sigma$ which maximizes the likelihood function $\mathcal{L}$ given by equation (3) after substituting into it probability function (4).[7]

[7]The algorithm for estimating a mixed logit model is explained in detail in Train (2003). We estimate the mixed logit model using Stata procedure mixlogit with 50 Halton draws. See Hole (2007) for estimation details.

### 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 $\alpha_i$ 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 a multinomial logit model without unobserved heterogeneity and a mixed logit model with random coefficients on the selected tariff attributes. The random coefficients allow for time-persistent heterogeneity in consumer preferences. The estimation results are shown in Tables 3 and 4 respectively. The likelihood-ratio test indicates that the mixed logit model is preferred to the multinomial logit model. The test statistic is equal to $\chi^2 = 2\ln(L_0/L_1) = -2 \cdot [-24,580 - (-24,805)] = 450$, while the critical value for sixteen degree of freedom (the number of random coefficients) is equal to $\chi^2(0.01, 14) = 32.00$. Therefore, we use the model with random coefficients in Table 4 to interpret the results.

The estimate of the coefficients on price is negative and highly significant in both models.[8] The estimates of the coefficients for all attributes of a mobile plan are positive and highly

[8]The tariff attributes included in the estimation should fully control for the quality of the tariff and we believe that the role of unobservable quality components is marginal. Nevertheless, the endogeneity of the price variable would arise if, for instance, some tariffs were highly promoted and at the same time priced higher. Failing to control for the promotion would bias the price coefficient in the positive direction but the other estimates should not be affected. Since our paper is focused on the interpretation of non-price coefficients our conclusions are still

significant, except for the dummies for the contract length which are negative. These attributes therefore significantly increase consumer valuation of the tariff. For instance, web only tariffs are positively valued by consumers, which may be due to lack of commitment or other advantages. They have positive valuation of tariffs with handset subsidy and of quadruple play tariffs with FTTH and ADSL fixed broadband access. As expected, consumers have negative valuation of the contractual commitment, where 12 month contracts appear to be less popular than 24 month contracts.[9]

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 the price coefficient is significant. They also differ with respect to the valuation of handset subsidy, web only tariffs, mobile data and voice allowance. The perception of substitution between unlimited voice minutes and fixed broadband access also varies across 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 governments in the European Union are trying 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. In addition, we allow these dummies to vary over time on a monthly basis, which for the mixed logit model is illustrated in Figure (1). The marginal value of FTTH in the fixed-mobile bundles increases over time, while the marginal value of ADSL decreases. In the first month of the data, January 2013, FTTH was valued more than ADSL by about 25% but at the end of 2013 it was valued two and a half times more. This may be due to the fact that consumers increasingly care about the speed of their

valid. One way to account for the endogeneity of price in discrete choice models is to apply the control function approach, which requires having instrumental variables for price (see Petrin and Train (2010)).

[9]This may be due to the way in which the firm provides information about commitment on the website and in the promotional leaflets, where 24 month contracts are shown as a default case.

Internet connection because of the growing range of products which require higher bandwidth such as data upload, IP TV and online video services.

We also use the mixed logit model to compute changes in the consumer surplus due to the introduction of quadruple play offers with ADSL and FTTH, as shown in Table (5).[10] We use formula (5) to calculate the difference in consumer surplus between the base case scenario, which is the current situation, and the case in which quadruple play tariffs with FTTH and/or ADSL are withdrawn from the market. The latter is equivalent to a situation, in which the price for quadruple play tariffs with ADSL and/or FTTH increases to a very high level, so that there are no consumers who choose these tariffs. As shown in Table (5), in December 2013 the consumer surplus would drop on average by about 7.0 Euros in the absence of fixed-mobile bundles with FTTH, by 1.1 Euros in the absence bundles with ADSL and by 8.4 Euros in the absence of quadruple play tariffs including any broadband access.[11] These averages are calculated for the whole sample of mobile users including those without quadruple play tariffs. For a 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 lower by 10.5 Euros on average. The effect of these tariffs on consumer surplus is greater because they are used by a larger number of consumers.

The results suggest that the introduction of quadruple play tariffs brings significant benefits to subscribers to mobile services. However, as already mentioned, an important limitation of our analysis is the fact that many consumers may combine a separate contract for mobile services with a 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 other estimation results suggest that consumers have positive marginal valuation of mobile data and voice minutes included in the tariff. They also positively value tariffs with an

[10] For the calculation we use 50 draws from the joint normal distribution and report mean values and standard deviations.

[11] These numbers do not add up because in the first two scenarios in the absence of quadruple play tariffs with one technology consumers switch to the other one, which mitigates the loss in consumer surplus.

unlimited volume of minutes. We include in the model the interaction terms between these tariff components to analyze how the consumer utility is impacted 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 mobile data and voice calls 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 an Over-The-Top service) is not a substitute to unlimited voice service. We also find that consumers value unlimited calling volume less when fixed VoIP is part of the 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. In general consumers who use newer handsets and smartphones are able to connect to the Internet at home via WiFi. They may therefore access the internet using a fixed broadband connection on their handsets instead of consuming mobile data.

Moreover, we find that there are significant switching costs between tariffs because of which consumers are not able optimize their choice of tariff. The estimation results suggest that switching costs are higher for consumers who still have a contract commitment and depend positively on the number of months left with commitment, i.e., the longer the commitment left the higher the 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. We also find that it is costly for consumers to leave the operator even though, as discussed above, the leaving dummy coefficient cannot be interpreted as a switching cost because of lack of information on where these consumers go.

To understand the impact of switching costs we calculate the difference between consumer surplus in the current situation and a hypothetical situation, in which switching costs between tariffs are set to zero. In the latter case we do not allow consumers to readjust their tariff choices. As shown in Table (5), in the absence of switching costs between tariffs consumer surplus would on average be higher by about 49.5 Euros in December 2013. This value represents the negative impact of switching costs on the utility. There is therefore a substantial loss in consumer surplus due to switching costs. Our results suggest that to a large extent switching costs are caused by consumers inertia rather than resulting from contractual commitment. In fact, we observe that 65% of consumers in our data switched a tariff at least once in the period of a year, see Table 2.

# 6 Conclusion

Quadruple play tariffs which include mobile voice and data, fixed IP voice, fixed broadband and IP TV are growing in popularity. 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 a European country which has full coverage of both broadband technologies: ADSL and FTTH.

Based on the mixed logit demand estimation we find that consumer valuation of FTTH broadband in 2013 increased over time, while ADSL lost attractiveness relative to FTTH and in absolute terms, which suggests that consumers increasingly care about the speed of connection offered by FTTH. Consumer surplus increased substantially due to 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 trying to stimulate the deployment of high speed Internet access via FTTH. If consumers were indifferent between ADSL and FTTH access, this policy would have no justification.

Since communications needs may be satisfied by voice and broadband delivered on mobile or fixed networks, another question is to what extent there is an additional value created when these services are sold jointly, i.e., whether they are complements or substitutes. 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 complete their online activity using fixed Internet access at home, with no download limit. Thus, fixed broadband services provide 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 a broadband connection.

Finally, we find that there are substantial switching costs between tariffs which restrict the ability of consumers to optimize their choice of tariff. Switching costs are higher for consumers with contractual commitment and depend positively on the number of months left with commitment. However, our results suggest that switching costs are to a large extent caused by consumers inertia rather than resulting from contractual commitment.

Even though we have the privilege of working with real consumer data, our analysis is limited by the fact that it comes from a single provider of mobile services and therefore we do not observe the full range of tariff choices available to consumers on the whole market.

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# Appendix

Table 1: Summary statistics of mobile tariffs

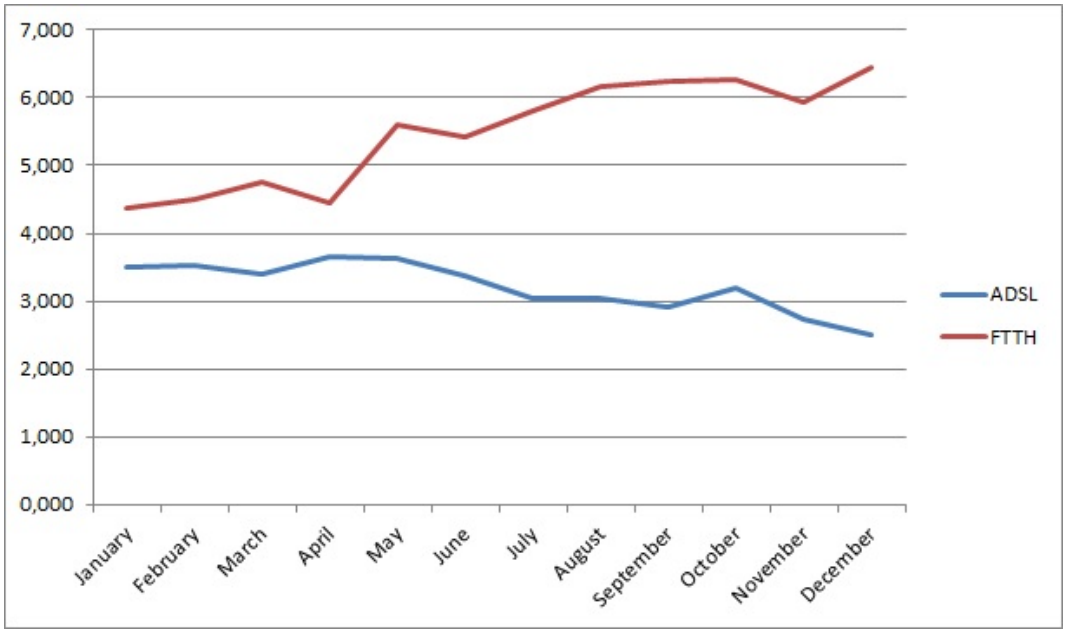
| New tariffs | | | | | |
|---|---|---|---|---|---|
| Variable | Obs | Mean | Std. | Min | Max |
| price | 211 | 40.12 | 23.46 | 4.9 | 100.99 |
| phone subsidy | 211 | 0.70 | 0.46 | 0 | 1 |
| adsl | 211 | 0.17 | 0.37 | 0 | 1 |
| ftth | 211 | 0.14 | 0.35 | 0 | 1 |
| sosh | 211 | 0.04 | 0.19 | 0 | 1 |
| datamobile | 211 | 1.17 | 1.45 | 0 | 6 |
| unlimited | 211 | 0.48 | 0.50 | 0 | 1 |
| voice limited | 211 | 48.82 | 53.39 | 0 | 180 |
| Old tariffs | | | | | |
| Variable | Obs | Mean | Std. | Min | Max |
| price | 352 | 39.54 | 20.91 | 4.99 | 100.5 |
| phone subsidy | 352 | 0.93 | 0.25 | 0 | 1 |
| adsl | 352 | 0.09 | 0.28 | 0 | 1 |
| ftth | 352 | 0.01 | 0.12 | 0 | 1 |
| sosh | 352 | 0.00 | 0.05 | 0 | 1 |
| datamobile | 352 | 0.64 | 0.92 | 0 | 4 |
| unlimited | 352 | 0.09 | 0.29 | 0 | 1 |
| voice limited | 352 | 115.28 | 83.83 | 0 | 480 |

In total there are 563 tariffs used in the estimation, of which 211 are new and 352 are old tariffs. There are between 43 and 65 different tariffs available to consumers each month.

Table 2: The number of consumers switching tariffs in 2013

| Number of tariff switches | Consumers | Percentage |
|---|---|---|
| 0 | 1,542 | 35% |
| 1 | 2,218 | 50% |
| 2 | 588 | 13% |
| 3 | 71 | 2% |
| 4 | 9 | 0% |
| 5 | 1 | 0% |
| Total | 4,429 | 100% |

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 3: Multinomial logit estimates

| Variables | Estimates | Months | ADSL | FTTH | Outside good |
|---|---|---|---|---|---|
| Price | -0.088*** | January | 2.807*** | 3.747*** | -6.152*** |
| | (0.002) | | (0.211) | (0.331) | (0.268) |
| Handset subsidy | 1.224*** | February | 0.003 | 0.043 | -0.587 |
| | (0.062) | | (0.208) | (0.342) | (0.411) |
| Contract 12 months | -1.368*** | March | -0.121 | 0.228 | -0.952** |
| | (0.148) | | (0.203) | (0.322) | (0.462) |
| Contract 24 months | -0.798*** | April | 0.117 | -0.136 | -0.657 |
| | (0.149) | | (0.194) | (0.353) | (0.440) |
| Low priced tariffs dummy | 2.144*** | May | 0.057 | 0.973*** | -1.684** |
| | (0.168) | | (0.195) | (0.294) | (0.753) |
| Mobile data | 0.332*** | June | -0.180 | 0.773*** | 1.295*** |
| | (0.041) | | (0.189) | (0.281) | (0.304) |
| Unlimited voice dummy | 3.273*** | July | -0.531*** | 1.103*** | 1.618*** |
| | (0.074) | | (0.184) | (0.267) | (0.294) |
| Voice volume | 0.013*** | August | -0.490** | 1.429*** | 1.475*** |
| | (0.000) | | (0.192) | (0.273) | (0.304) |
| Mobile data + unlimited | 0.087** | September | -0.615*** | 1.428*** | 1.946*** |
| | (0.041) | | (0.191) | (0.269) | (0.291) |
| Mobile data + broadband | 0.152*** | October | -0.370* | 1.456*** | 2.108*** |
| | (0.029) | | (0.207) | (0.273) | (0.291) |
| Unlimited voice + broadband | -1.071*** | November | -0.810*** | 1.126*** | 1.894*** |
| | (0.157) | | (0.198) | (0.270) | (0.295) |
| Voice volume + broadband | -0.003* | December | -0.992*** | 1.640*** | 2.093*** |
| | (0.002) | | (0.201) | (0.264) | (0.293) |
| Switching tariff | -7.698*** | | | | |
| | (0.050) | | | | |
| Switching tariff with contract | -0.368*** | | | | |
| | (0.063) | | | | |
| Switching tariff with time left | -0.068*** | | | | |
| | (0.003) | | | | |
| Switching to low priced tariffs | -3.398*** | | | | |
| | (0.143) | | | | |
| Switching to tariffs with FTTH | -1.295*** | | | | |
| | (0.182) | | | | |
| Leaving - with contract | -0.926*** | | | | |
| | (0.165) | | | | |
| Leaving - time left | 0.016 | | | | |
| | (0.012) | | | | |
| LL | -24,805 | | | | |
| Observations | 2,824,329 | | | | |

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: Mixed logit estimates

| Variables | Mean | STD | Months | ADSL | STD | FTTH | STD | Outside good | STD |
|---|---|---|---|---|---|---|---|---|---|
| Price | -0.111*** | 0.011*** | January | 3.497*** | -0.030 | 4.372*** | 0.134 | -7.505*** | 1.215*** |
| | (0.002) | (0.003) | | (0.240) | (0.102) | (0.358) | (0.237) | (0.348) | (0.229) |
| Handset subsidy | 2.217*** | -1.350*** | February | 0.020 | | 0.115 | | -0.593 | |
| | (0.133) | (0.129) | | (0.209) | | (0.341) | | (0.443) | |
| Contract 12 months | -1.419*** | -0.009 | March | -0.095 | | 0.383 | | -0.831* | |
| | (0.179) | (0.080) | | (0.206) | | (0.323) | | (0.490) | |
| Contract 24 months | -0.872*** | -0.039 | April | 0.161 | | 0.082 | | -0.407 | |
| | (0.180) | (0.076) | | (0.196) | | (0.349) | | (0.464) | |
| Low priced tariffs dummy | 3.000*** | 0.335 | May | 0.138 | | 1.216*** | | -1.469* | |
| | (0.247) | (0.273) | | (0.198) | | (0.296) | | (0.770) | |
| Mobile data | 0.469*** | 0.119*** | June | -0.113 | | 1.054*** | | 1.725*** | |
| | (0.053) | (0.042) | | (0.194) | | (0.284) | | (0.333) | |
| Unlimited voice dummy | 3.874*** | 0.154* | July | -0.456** | | 1.433*** | | 2.160*** | |
| | (0.094) | (0.088) | | (0.189) | | (0.272) | | (0.324) | |
| Voice volume | 0.015*** | 0.006*** | August | -0.464** | | 1.783*** | | 2.047*** | |
| | (0.001) | (0.000) | | (0.200) | | (0.278) | | (0.333) | |
| Mobile data + unlimited | 0.027 | -0.045 | September | -0.580*** | | 1.863*** | | 2.579*** | |
| | (0.054) | (0.045) | | (0.199) | | (0.275) | | (0.325) | |
| Mobile data + broadband | 0.165*** | 0.117* | October | -0.296 | | 1.901*** | | 2.835*** | |
| | (0.044) | (0.070) | | (0.220) | | (0.280) | | (0.325) | |
| Unlimited voice + broadband | -1.479*** | -0.662*** | November | -0.765*** | | 1.570*** | | 2.646*** | |
| | (0.210) | (0.165) | | (0.209) | | (0.277) | | (0.331) | |
| Voice volume + broadband | -0.004** | 0.001 | December | -0.985*** | | 2.072*** | | 2.877*** | |
| | (0.002) | (0.001) | | (0.213) | | (0.272) | | (0.331) | |
| Switching tariff | -8.004*** | 0.576*** | | | | | | | |
| | (0.061) | (0.045) | | | | | | | |
| Switching tariff with contract | -0.467*** | | | | | | | | |
| | (0.072) | | | | | | | | |
| Switching tariff with time left | -0.078*** | | | | | | | | |
| | (0.004) | | | | | | | | |
| Switching to low priced tariffs | -4.321*** | | | | | | | | |
| | (0.213) | | | | | | | | |
| Switching to tariffs with FTTH | -1.285*** | | | | | | | | |
| | (0.191) | | | | | | | | |
| Leaving - with contract | -1.159*** | | | | | | | | |
| | (0.195) | | | | | | | | |
| Leaving - time left | 0.013 | | | | | | | | |
| | (0.013) | | | | | | | | |
| LL | -24,580 | | | | | | | | |
| Observations | 2,824,329 | | | | | | | | |

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 5: Difference in average consumer surplus (in Euros)

| Month | No FTTH | | No ADSL | | No ADSL & FTTH | | No web only | | No switching costs | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std | Mean | Std | Mean | Std | Mean | Std | Mean | Std |
| January | 0.54 | 0.02 | 3.97 | 0.06 | 4.63 | 0.06 | 8.36 | 0.07 | -54.84 | 0.18 |
| February | 0.72 | 0.02 | 3.92 | 0.06 | 4.75 | 0.06 | 9.31 | 0.07 | -54.07 | 0.17 |
| March | 0.95 | 0.02 | 3.71 | 0.06 | 4.79 | 0.06 | 9.67 | 0.06 | -53.88 | 0.17 |
| April | 0.90 | 0.02 | 3.33 | 0.05 | 4.29 | 0.06 | 9.27 | 0.07 | -53.89 | 0.16 |
| May | 1.29 | 0.03 | 3.22 | 0.05 | 4.68 | 0.06 | 10.05 | 0.07 | -53.31 | 0.17 |
| June | 1.61 | 0.03 | 2.71 | 0.05 | 4.54 | 0.06 | 9.37 | 0.08 | -52.28 | 0.16 |
| July | 2.22 | 0.04 | 2.06 | 0.04 | 4.54 | 0.06 | 9.47 | 0.08 | -53.82 | 0.17 |
| August | 3.27 | 0.05 | 1.97 | 0.05 | 5.48 | 0.07 | 10.16 | 0.08 | -51.97 | 0.17 |
| September | 3.99 | 0.05 | 1.68 | 0.04 | 5.95 | 0.07 | 9.88 | 0.08 | -50.80 | 0.17 |
| October | 5.17 | 0.07 | 1.83 | 0.04 | 7.37 | 0.09 | 10.24 | 0.08 | -47.53 | 0.16 |
| November | 5.63 | 0.07 | 1.38 | 0.04 | 7.31 | 0.08 | 10.49 | 0.08 | -48.95 | 0.15 |
| December | 7.02 | 0.08 | 1.06 | 0.03 | 8.38 | 0.10 | 10.39 | 0.09 | -48.55 | 0.15 |

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.