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Transition from copper to Fiber Broadband: The Role of Connection Speed and Switching Costs

Abstract

We estimated a mixed logit model using data on the broadband technologies chosen by 94,388 subscribers of a single European broadband operator on a monthly basis between January and December 2014. We found that consumers have similar valuation of DSL connection speeds in the range between 1 and 8 Mbps. Moreover, in January 2014, the valuation of FttH connections with a speed of 100 Mbps was not much higher than of DSL connections with a speed of 1 to 8 Mbps, but it has increased quickly over time. The small initial difference in the valuation of DSL and FttH connections may be because consumers' basic Internet requirements such as browsing, emailing, reading news, shopping, and even watching videos online could be satisfied with a connection speed below 8 Mbps. We also found that consumers face significant switching costs when changing broadband tariff plans, which are substantially higher when switching from DSL to FttH technology. According to counterfactual simulations based on our model, switching costs between technologies are the main factor which slows down consumer transition from DSL to FttH.

JEL-Codes: L430, L500, L960.

Keywords: FttH, DSL, connection speed, switching costs.

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1 Introduction

In the last few years, the European Commission has been pursuing the objective of providing fixed broadband Internet access to all households in the European Union (EU). But apart from universal broadband coverage, the Commission increasingly cares about access quality in terms of broadband speed. According to the Digital Agenda for Europe, by 2020, all EU households should benefit from a connection speed of at least 30 Mbps and at least 50% of EU households should have a connection speed of 100 Mbps or more.[1] In September 2016, the Commission further announced that by 2025 all European households should have access to connections with a speed of at least 100 Mbps. To achieve this objective, the Commission proposed "a new European Electronic Communications Code including forward-looking and simplified rules that make it more attractive for all companies to invest in new top-quality infrastructures, everywhere in the EU, both locally and across national borders." According to the Commission, these investments could "boost the GDP of the EU by an additional 910 billion euros and create 1.3 million new jobs by 2025".[2] Furthermore, the roll-out of high speed broadband access should enable the development of new and enhanced digital services, enhancing consumer welfare and increasing the competitiveness and reach of EU businesses.

Broadband services were originally provided using two technologies: (i) Digital Subscriber Line (DSL) technology which relies on copper networks and offers speeds of up to 8 Mbps and (ii) cable modem technology which uses access lines for cable television, upgraded to coaxial cables to provide simultaneous transmission of data, television and voice communications.[3] From 2010 onwards, incumbent telecommunications operators and new entrants in Europe started to invest in fiber optic networks, which are rolled out up to the customer's door (Fiber to the Home or FttH) and can carry video, data, voice and interactive video-telephone services. FttH connections should offer speeds of 100 Mbps and more, which satisfies the objectives set out by

[1] "A Digital Agenda for Europe," European Commission, COM(2010) 245.

[2] Source: "State of the Union 2016: Towards a Better Europe - A Europe that Protects, Empowers and Defends"

[3] The highest DSL connection speed is 8 Mbps. ADSL2+ and VDSL technologies, which enable more efficient use of copper lines, provide higher speeds from 8 Mbps up to 50 Mbps for homes located close to the exchange. These advanced technologies are not available to all consumers.

the Commission. However, as of June 2015, about 70% of EU households with a fixed broadband connection relied on DSL technology.[4] The main reason for such a high proportion of slower DSL connections was that alternative high-speed technologies such as FttH and cable modems are still not available to the majority of EU households. In countries where cable coverage is similar to DSL both technologies have comparable market shares.[5]

Since the liberalization of fixed-line telecommunications markets in 1998, policy and academic debates have focused on how to regulate access to fixed broadband infrastructure owned by the former monopolies and to provide incentives to firms to invest in high-speed broadband networks. But the relatively small proportion of high-speed broadband technologies may also be influenced by consumers' needs and preferences with respect to the Internet access and by difficulties in switching to other broadband technologies. First, DSL users may have no idea which broadband technology they currently use to access the Internet and how the quality of the connection would change if they switched from DSL to FttH or a cable modem. In this respect, broadband technologies seem to resemble experience goods. Second, there may be substantial switching costs due to transaction costs, uncertainty and other reasons, which may hold back consumers from changing tariffs, operators and adopting higher-speed technology. Third, the possible price difference between DSL and FttH services may be too high compared to the benefits perceived by consumers to justify switching. Finally, the presence of indirect network externalities may also initially slow down fiber adoption. On the one hand, consumers will switch from copper to fiber technology if they can access new online content and services. On the other hand, new online content and services will only be developed if there are enough consumers with high-speed broadband connections.[6] For these reasons, it may be a challenge to achieve the Commission's

[4] Source: European Commission 2015 Digital Scoreboard.

[5] As of December 2014, only 6% of households in the EU had access to fiber, 19% to cable broadband and 4% to other fixed broadband technologies. At the same time, about 59% of households had access to DSL, with large differences across Member States determined by the development of fixed-line infrastructure. Historically, Central and Eastern European countries had poorer fixed-line infrastructure and, as a result, now have lower DSL coverage compared to the almost complete coverage in most Western European countries. Source: 2015 EU Digital Single Market Report.

[6] For instance, Baranes (2014) theoretically analyzes interplay between network investment and content quality on the Internet.

broadband access objectives on time. According to the EU Digital Single Market Report, in December 2014, only 26% of fixed broadband subscriptions in the EU had speeds of over 30 Mbps and 9% of over 100 Mbps.

In this paper, we analyze the role of connection speeds and switching costs between tariffs and technologies in the transition from DSL to FttH. More specifically, we focus on consumers' choices of broadband tariffs based on DSL and FttH networks when both technologies are available at the consumers' homes. We used information on broadband technologies used by 94,388 subscribers of a single broadband operator in a European country on a monthly basis between January and December 2014. We estimated a mixed logit model of demand for broadband tariffs according to tariff characteristics including the price and speed of DSL connections. In addition, we considered that consumers may face resistance when changing tariffs and technologies due to switching costs, which may therefore slow down their transition from copper to fiber technology. We used the estimated model to conduct counterfactual simulations, which illustrate the relative importance of broadband speeds and switching costs for consumers' choices between DSL and FttH connections.

We found that in January 2014 the valuation of speeds between 1 and 8 Mbps was very similar, which may be because consumers' basic Internet requirements such as browsing, emailing, reading news, shopping and even watching videos online could be satisfied with connection speeds within this range. Surprisingly, the initial valuation of an FttH connection with a speed of 100 Mbps was very similar to that of a DSL connection with a speed between 1 and 8 Mbps but it increased quickly over time. In February 2014, the first month of our data, the valuation of an FttH connection with a speed of 100 Mbps was only 2.9% higher than the valuation of a DSL connection with a speed of 8 Mbps and was 7% higher than the valuation of a DSL connection with a speed of 1 Mbps. In December 2014, the last month of our data, the valuation of an FttH connection was 59% higher than that of a DSL connection with a speed of 8 Mbps and was 66% higher than that of a DSL connection with a speed of 1 Mbps. Increasing valuation over time reflects a growing need for high-speed connections, which may be due to the availability of new online services and marketing of FttH connections. Furthermore, we found that consumers face significant switching costs when changing broadband tariffs and technologies. Switching costs are substantially higher when consumers switch from DSL to FttH tariffs, which may be due to additional costs needed to set up the first FttH connection. In particular, consumers must make an appointment with a technician who will then visit their house to set up a connection.

Our counterfactual simulation shows that adoption of FttH among subscribers who are eligible for these connections, which stands at 29% in the last period in our data, would increase to 54% in the absence of switching costs from DSL to FttH technology. In the absence of switching costs between tariffs, the proportion of FttH connections would not change at all, while in the absence of both technology and tariff switching costs it would be about 62 percentage points higher reaching 91%. Switching costs between tariffs may be due to transaction costs, uncertainty and a lack of information about other tariff plans, while switching costs between technologies may be related to time and cost of installation.

In further counterfactual simulations we consider the role of speed in adoption of FttH technology in the presence and absence of switching costs. If the speed of all DSL connections varied between 1 Mbps and 50 Mbps in the presence of switching costs, the proportion of FttH connections would remain at 29%. Moreover, if the speed of all DSL connections varied between 1 Mbps and 8 Mbps in the absence of switching costs, the proportion of FttH connections would remain almost unchanged at 91%. But if the speed of all DSL connections increased to 50 Mbps, the proportion of FttH connections would decrease of 77%. These counterfactual simulations suggest that switching costs between technologies are the main factor slowing down the consumer transition from DSL to FttH. Upgrading all DSL lines to ADSL2+ and VDSL technologies with a hypothetical speed of 50 Mbps, has a relatively small impact on the transition. In the final counterfactual simulation, we found that current pricing of DSL and FttH services does not slow down the transition process. The premium of 5 euros paid by consumers for an FttH connection makes it attractive compared to the much slower DSL connection. This relatively small premium reflects the operator's strategy to stimulate the technology transition.

The remainder of the article is organized as follows. Section 2 discusses relevant empirical literature. Section 3 presents the data used in the estimation. Section 4 introduces the empirical model. Section 5 presents the results of the estimations and counter-factual simulations. Finally, Section 6 concludes.

2 Literature review

Due to lack of detailed consumer-level information on technology choices over time, the literature on adoption of broadband technologies relies mainly on aggregate country-level data. For instance, Distaso et al. (2006) and Bouckaert et al. (2010) use data on EU and OECD countries respectively to analyze the role of inter- and intra-platform competition for broadband diffusion.[7] Dauvin and Grzybowski (2014) study the same question using more detailed NUTS 1 regional data for the EU countries. Among the few studies which focus on fiber adoption, Wallsten and Hausladen (2009) use data for 27 EU countries from 2002 to 2007 and conclude that the adoption of Fttx technology is lower in countries in which local loop unbundling is more effective. More recently, Briglauer (2014) uses data for 27 EU countries from 2004 to 2013 and finds that more effective regulatory-induced service-based competition has a negative impact on Fttx subscriptions.

There is also a growing body of literature studying substitution between broadband technologies based on individual-level data. For instance, Cardona et al. (2009) use survey data of households in Austria to estimate discrete choice models for Internet access via DSL, cable and mobile broadband and conclude that there is substitution between fixed and mobile broadband. Grzybowski et al. (2015) estimate a mixed logit model for households' choices of broadband technologies in Slovakia and use the estimates of price elasticities to conclude that mobile broadband should be included in the market definition for DSL. In another paper, Srinuan et al. (2012) use a discrete choice model and survey data for Sweden and find that mobile broadband and fixed broadband technologies are close substitutes when they are locally available.

There are also a few studies which analyze the migration from old to new technologies. For instance, Ida and Kuroda (2006) use survey data and estimate a discrete choice model to analyze migration from narrowband to broadband in Japan. In another paper, also for Japan, Ida and Sakahira (2008) analyze migration from DSL to FttH technology. They identify income, service

[7] We talk about inter-platform competition when entrants build their own infrastructure using different technologies and intra-platform competition when entrants lease access to incumbents' facilities via local loop unbundling. Local loop unbundling is the regulatory process of allowing multiple telecommunications operators to use connections from the telephone exchange to the customer's home.

usage such as motion-picture viewing, and types of residence as primary determinants of FttH subscriptions. They also conclude that there is a significant lock-in effect in technology adoption but their study relies on survey data from a single time period.

In this paper, we analyze the role of switching costs in the adoption of broadband technologies following the approach used by Grzybowski and Liang (2015). They estimated a mixed logit model using data on subscribers to mobile services from a single European operator and found that there are substantial switching costs between tariffs which reduce consumer surplus. In this paper, we use a sample of fixed broadband service subscribers. Some of them use quadruple play tariffs which bundle fixed and mobile services.

Our paper is also related to studies which analyze the role of broadband connection speeds. For instance, Rosston, Savage and Waldman (2010) use discrete choice experiments to estimate the marginal willingness to pay for improvement in broadband services in the US in 2003 and 2010. They show that customers' willingness to pay for speed is rather low and increases with education, income and on-line experience. A US household is willing to pay $3 more in order to enjoy ultra-fast broadband rather than basic broadband. In another related paper, LaRose et al. (2014) find that experience has a positive effect on speed valuation, which suggests that use of broadband technologies is similar to experience goods. In another related paper, Ahlfeldt et al. (2016) show that having access to a fast Internet connection is an important determinant of capitalization effects in property markets in the UK. They find that an upgrade from narrowband to broadband connection with Internet speed up to 8 Mbps could increase the price of an average property by as much as 2.8%. But a further increase to a faster connection offering speeds up to 24 Mbps leads to an incremental price effect of only an additional 1%. Their result suggest therefore that there are diminishing returns to speed, which is also the finding in our paper.

3 The Data

We used two unique data sets, which were made available to us by a European telecommunications provider of both fixed and mobile services. The first database includes information on fixed broadband tariffs used by a few million customers of the firm on a monthly basis from January 2014 to December 2014. From the whole customer database, we solely retained consumers with homes connected to the fiber network, i.e., consumers who are eligible for FttH access. We then randomly drew 100,000 consumers. Consumers who left the operator in a given month were replaced by the same number of randomly drawn new arrivals. We lost a number of consumers due to data cleaning. We dropped consumers using older broadband tariffs for which we do not have detailed information. The final sample consists of 94,388 consumers. These customers have subscribed to one of the operator's broadband offers: (i) a 'naked' Internet access offer via DSL or FttH; (ii) a 'double play' offer which includes Internet access and fixed telephony over IP (IP telephony); (iii) a 'triple play' offer which includes Internet access with IP telephony and television over IP (IPTV); or (iv) a 'quadruple play' offer which includes IP telephony, IPTV and access to mobile services. We also have information on whether consumers have kept their fixed-line connections for voice calls (PSTN), in which case they pay extra for it. Moreover, for each quadruple play consumer we know the number of months remaining in their commitment period.

For 58,455 customers in this sample we have information on the copper line quality in terms of DSL connection speed, with values ranging between 1 and 8 Mbps, which is determined by copper loss.[8] Table 4 shows the number of consumers in our sample with a given copper line loss and the corresponding DSL connection speed.[9] Importantly, the price charged by the operator for DSL access does not depend on speed. Besides, the speed of an FttH connection is approximately 100 Mbps and is not dependent on the distance from the consumer's house to

[8]Broadband signals from the exchange suffer attenuation as they travel along the copper line from the exchange to customer's house, which reduces the speed of DSL access. In general, the further a customer's house is from the exchange, the more copper loss they experience. The copper line loss was measured in decibels in December 2010 or December 2013 and ranges from 1.5 dB to 75 dB with a mean value of 27 dB.

[9]In this analysis we have ignored the fact that some consumers who live close to the exchange may use ADSL2+ and VDSL connections with speeds between 8 Mbps and 50 Mbps.

the exchange.[10]

The second database includes information on: (i) 'new' fixed broadband offers based on DSL and FttH technologies, which were available to consumers in each month during the period of our analysis and (ii) 'old' offers which some consumers continue to use but which can no longer be selected by other consumers in our sample. For each triple-play offer we have information about the price, technology, the length of the contractual commitment and whether a fixed-line PSTN connection has been kept by the consumer in case of DSL technology. For quadruple play offers, the additional attributes include services which are available on mobile phones. In particular, we have information about voice and data allowances, whether a handset subsidy is included in the offer and the length of the contractual commitment. We also know whether the tariff is a low cost contract without commitment which can only be purchased online. The information on available tariffs was used to create a choice set for each consumer, as explained below.

These two data sets are completed with additional municipality-level information. For each consumer, we have information about the postal address and unique postcode which can be linked to one of about 36,000 municipalities in the country considered. We used the postcodes to merge data on individual consumers with socio-economic variables at a municipality level, including average income, the unemployment rate, the proportion of the population who have passed their baccalaureate and the proportion of the population with a university degree. We used these variables to control for observable consumer preferences in the adoption of FttH technology. Moreover, for each municipality we know whether there was a cable network available that was upgraded to FttLA (Fiber to the Last Amplifier) technology, which can provide high speed broadband connections of above 30 Mbps. This information was extracted from the websites of

[10]The operator has adopted a Gigabit Passive Optical Network (GPON) fiber architecture, which may give users a different speed experience compared to the Point to Point (P2P) architecture adopted by other competitors on the market. According to the operator it is reasonable to assume that consumers can achieve a speed of 100 Mbps on their FttH connections.

cable operators.[11]

4 Econometric Model

Our modeling approach is closely related to Grzybowski and Liang (2015) who studied the role of switching costs in consumers' choices of mobile telecommunications services. We defined the choice set and switching costs in the same way they did in their paper.

The Choice Set

We constructed the choice set for each month in the following way. 'Old' consumers, who were already subscribers to our operator's broadband services in the first month of the data, can decide to: (i) keep their old tariff; (ii) switch to a new tariff from the list of offers available in a given month; (iii) cancel their current operator's services. 'New' consumers in the first period do not the option (i) to keep their old tariff in their choice set.

We determined the set of 'new' tariffs in each month using the subscriptions database. We considered 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 was considered as '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 was 228, out of which 139 were quadruple play tariffs. The number of available 'new' tariffs ranged between 108 and 139 per month.[12] The remaining tariffs to which consumers subscribed are considered to be 'old' tariffs. In total, 122 unique 'old' tariffs were used by consumers in our sample during 2014.

A consumer's complete choice set in a given month consists of 'new' tariffs in this month and in the case of 'old' consumers includes the tariff they had in the previous period. However, since

[11] We also extracted information from online sources on the presence of other fiber operators in the municipalities. But since they were present in the same municipalities in which our operator deployed FttH, thus affecting all consumers in our sample, this information was not used in the estimation.

[12] A new catalogue with about 38 tariffs, which differ with respect to some attributes, is released every 3 months.

consumers may not be aware of all the tariffs which are on offer, an alternative approach involves limiting the choice set by randomly drawing a number of tariffs from the complete choice set. Due to the large size of our sample and choice set, we estimated a model which consists of 4-5 choice alternatives. Thus, 'old' consumers who do not switch tariff have the following four choice alternatives: (i) their 'old' tariff; (ii) a 'new' DSL tariff which is randomly drawn from the list of offers available in a given month; (iii) a 'new' FttH tariff which is randomly drawn from the list of offers available in a given month; (iv) an outside option to leave the operator. It is important that the choice set of 'old' consumers who switch tariffs must include the newly selected tariff. Thus, 'old' consumers who switch have a 5th choice in their choice set: the 'new' tariff to which they switch. 'New' consumers, on the other hand, have four alternatives in their choice set: (i) the selected 'new' tariff; (ii) a 'new' DSL tariff which is randomly drawn from the list of offers available in a given month; (iii) a 'new' FttH tariff which is randomly drawn from the list of offers available in a given month; (iv) an outside option to leave the operator.[13]

In general, consumers who do not opt for quadruple play tariffs combine triple-play broadband services from our operator with mobile services from our operator or any of the competitors. These services can be either prepaid or postpaid. Moreover, consumers who choose the option of (iv) leaving our provider can also mix and match broadband and mobile services from other operators.

The utility a consumer derives from these tariffs depends on the set of attributes. The attributes of broadband-only tariffs are: (i) the monthly list price; (ii) access to the Internet via DSL or FttH technology; (iii) the commitment period; (iv) a fixed-line PSTN connection. The attributes of quadruple play tariffs are: (i) the monthly list price; (ii) access to the Internet via DSL or FttH technology; (iii) the commitment period; (iv) whether a handset subsidy is offered or just a SIM card without a subsidy; (v) whether voice minutes are unlimited and, if not, the volume of minutes included; and (vi) the mobile data allowance in GB. In the case of DSL

[13] We also estimated a model with a choice set including all 'new' tariffs available in a given month which greatly increases the size of dataset. We were able to estimate a multinomial logit model which yields almost identical results, except for the switching dummy coefficient which increases in magnitude. However, the size of the dataset makes it impossible to estimate a mixed logit model within a reasonable timeframe.

offers, the additional information is the connection speed, which is determined by the copper line loss of the consumer's connection. We constructed a set of dummy variables for discrete tariff characteristics and otherwise used continuous variables. Table (1) shows summarized statistics for 'new' and 'old' tariffs which are used by consumers in our dataset.

Switching tariff plans is common. The total number of tariff switches made by consumers in our sample in 2014 is 46,760 out of 992,550 monthly tariff choice observations, which represents 4.7%. There is some variation in the number of switches per month ranging between 3.3% and 5.5%. Table 3 shows the number of switchers in the database, which indicates that 60% never changed tariff, 32% switched once, 7% twice and 1% three times or more. These numbers suggest that switching tariffs in a one year period is relatively frequent but less common than for mobile services, as reported in Grzybowski and Liang (2015).

The Model

We estimated a discrete choice model assuming that each individual in a given month chooses a tariff which maximizes their utility from the choice set described above. We used a standard linear utility specification which depends on tariff attributes as well as observable and unobservable individual characteristics. We accounted for the heterogeneity in preferences using random coefficients on price and switching cost dummies. Each individual's utility $i = 1, ..., N$ derived from tariff $j = 1, ..., J$ in month t is given by:

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

where the tariff price is expressed as p_{jt}, and α_i is the individual-specific valuation of the price. Note that all consumers observe the same tariff prices which are independent of their usage. For broadband-only tariffs (triple play), the x'_{jt} vector includes several variables: (i) a dummy for DSL broadband (Triple DSL); (ii) a dummy for FttH broadband (Triple FttH); (iii) dummies for 12- and 24-month contracts (Contract 12 TP and Contract 24 TP); (iv) a dummy for a fixed-line PSTN connection (PSTN line). For quadruple play tariffs, the following variables were included: (i) a dummy for DSL broadband (Quadruple DSL); (ii) a dummy for FttH broadband (Quadruple FttH); (iii) dummies for 12- and 24-month contracts (Contract 12 QP and Contract

24 QP); (v) a dummy for a handset subsidy (Handset subsidy); (vi) a dummy for unlimited voice minutes (Unlimited voice); and (vii) mobile data included in the offer (Mobile data). We also associated dummy variables for DSL and FttH connections for both triple and quadruple play tariff plans with monthly time trends (DSL time and FttH time). In addition, for a sub-sample of 58,455 consumers we used a set of dummy variables for DSL connection speeds of 1, 2, 5, 7 and 8 Mbps (DSL speed of 'X' Mbps) and for a FttH connection speed of 100 Mbps (FttH speed of 100 Mbps). The speed dummy variables cannot be estimated together with dummy variables for technologies due to collinearity. Therefore, we estimated two model specifications: one (i) with technology dummy variables; and the other (ii) with speed dummy variables.

The switching dummies vector is expressed as s'_{ijkt} and the coefficients vector γ_i represents the disutility from switching, which approximates 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 incurring some switching costs, which may be higher when this switch also involves switching technology; (iii)) stop using their tariff and leave for another operator, in which case there are also some switching costs to pay. Switching costs cause inertia, leading consumers to keep their current plan, even though alternative tariffs may be more attractive in terms of attributes and prices. When 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 the same applies when a consumer chooses to leave for another operator.

We defined three types of switching cost variables in the following way. First, the switching costs dummy equals zero when consumer i considers choosing the same tariff $k = j$ in month t as in the previous month $t - 1$, and one for all alternative tariffs $k \neq j$ in the choice set. This switching dummy is interpreted as the disutility related to switching to an alternative tariff, which we refer to as switching costs between tariffs. For users of quadruple play tariffs, we also have information about the number of months remaining in the commitment period, which may influence the consumer's ability to switch tariff or to leave the operator. Thus, switching costs can vary depending on the number of months left in the commitment period. Second, consumers who did not have FttH before may have higher switching costs because a technician must visit their house to set up the initial fiber connection. There may also be additional costs for FttH users who decide to switch back to DSL. We refer to these additional costs as switching costs between technologies. Third, the switching cost dummy for leaving the operator equals zero when choosing any tariff, including the one selected before, and equals one for the outside option of leaving the operator. This is the disutility (or benefit) related to leaving the operator, which we refer to as a leaving dummy.[14]

It can be difficult to identify switching costs in the presence of unobserved time-persistent preferences (see Heckman (1981)). Consumers may continue using the same tariff and technology because it better fits their individual tastes and needs. We allowed for unobserved time-persistent individual preferences by means of a mixed logit estimation for panel data. We used two random coefficients in the estimation: (i) on price and (ii) on switching costs, which both introduce correlation of individual consumer preferences over time.[15] The problem of consumer inertia in our context should be less of an issue because we considered consumers' choices of different tariffs and technologies from the same firm. Consumers do not have persistent idiosyncratic preferences for broadband connections based on DSL or FttH technology. What essentially differentiates these two technologies, apart from the price and speed, for which we controlled, is the physical installation and modem which is used to connect to the network.

Finally, ϵ_{ijt} is the individual-specific valuation of tariff j at time t, i.e., the "logit error term". It is assumed to be identically and independently distributed over the tariffs and individuals according to a type I extreme value distribution. The random coefficients $(\alpha_i, \gamma_i)'$ can be written as: $(\alpha, \gamma)' + \nu_i$, where (α, γ) are mean valuations and $\nu_i \sim N(0, \Sigma)$ is a randomly drawn vector

[14] The lack of precise information about what consumers do when they choose the outside option causes a problem with the identification of the costs of switching to the outside option. This is because a dummy variable for switching to the outside option is equivalent to a dummy variable for the valuation of the outside option. Hence, this dummy variable represents a combination of disutility from switching and the utility a consumer derives from the outside option. The interpretation of this dummy variable as switching costs is not appropriate. In the case of switching to alternative tariffs, since there are no tariff dummy variables 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 switching dummy coefficient can be interpreted as switching costs.

[15] There is a limit on the number of random coefficients we can use because of the large size of our dataset and long estimation time.

from a normal distribution with Σ representing a diagonal matrix, elements of which represent standard deviations around the mean valuations.

An individual i chooses in month t 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. The expression for the probability of individual i making a sequence of tariff choices in the considered time period and estimation strategy are shown in Grzybowski and Liang (2015). The algorithm for estimating a mixed logit model is explained in detail in Train (2003).[16] After the estimation, we conducted counterfactual simulations, in which we calculated changes in the proportion of FttH connections and in the consumer surplus after removal of switching costs and as a result of changes in DSL connection speeds (see Small and Rosen (1981) for the consumer surplus formula).

5 Estimation Results

The estimation results for the mixed logit model are shown in Table 5. We estimated two model specifications: (i) Model I without connection speeds but with DSL and FttH dummy variables; and (ii) Model II with a set of dummy variables for the speed of connections. The DSL connection speed depends on the copper line loss and is the same for all DSL tariffs in the choice set of an individual consumer. It varies across consumers within the range of possible values, i.e. 1, 2, 5, 7 and 8 Mbps, for which dummy variables are constructed. The speed of an FttH connection is assumed to be 100 Mbps for all consumers. The estimation results are insensitive with respect to the assumption of an FttH connection speed of 100 Mbps, which we tested using alternative speed values of 50 and 200 Mbps.[17] We cannot estimate a model which includes both the connection speeds and technology dummy variables because of collinearity. The first estimation was conducted using a sample of 94,388 consumers and the second estimation using a sample of 58,455 consumers due to missing data on DSL connection speeds for the remaining

[16] We estimated the mixed logit model using the Stata mixlogit command. See Hole (2007) for estimation details.

[17] The log-likelihood value is also lower for models with FttH speeds of 50 Mbps and 200 Mbps than with 100 Mbps.

consumers.

In the first estimation without connection speeds, consumers have a positive valuation of DSL and FttH connections compared to the choice of the outside option. The valuation is higher for FttH, which is due to a higher connection speed. But the valuation of FttH connections may also be influenced by marketing activities and other factors. The technology dummy variables are also associated with the time trend, which is significant and positive for the FttH technology. Thus, the valuation of FttH is increasing over time relative to the valuation of DSL.

In the second estimation, speed dummy variables were also interacted with the time trend. The estimated coefficients on speed dummy variables are very similar, which suggests that consumers have almost the same valuation of DSL connections with speeds of 1, 2, 5, 7 and 8 Mbps. Surprisingly, the valuation of a speed of 100 Mbps is not much higher in the first month in the data. The interaction term of the dummy variable for an FttH speed of 100 Mbps with the time trend is significant and positive, while it is insignificant for DSL speed dummy variables, except a significant but very small coefficient for a connection speed of 7 Mbps. Thus, the valuation of fiber access increases over time, which may reflect a growing demand for Internet-based multimedia applications, such as online streaming, data clouds, IPTV and other bandwidth-intensive applications. Moreover, there are also intensive marketing actions which try to convince consumers to subscribe to FttH in cities in which consumers have this option.

In February 2014, the second month of our data, the valuation of an FttH connection with a speed of 100 Mbps was $(8.929 + 0.551 * 2 - 9.750)/9.750 = 2.9\%$ higher than the valuation of a DSL connection with a speed of 8 Mbps and $(8.929 + 0.551 * 2 - 9.376)/9.376 = 7.0\%$ higher than the valuation of a DSL connection with a speed of 1 Mbps. In December 2014, the last month of our data, the valuation of an FttH connection was 59% higher than the valuation of a DSL connection with a speed of 8 Mbps and 66% higher than the valuation of a DSL connection with a speed of 1 Mbps. Thus, consumers have a decreasing valuation of speed, which may be due to the fact that many key online activities such as emailing, reading news, shopping, browsing and even watching videos does not require speeds above 8 Mbps.[18] Our results confirm the findings in Ahlfeldt et al. (2016) who conclude that there are diminishing returns to speed, which are measured by impact of speed on property prices in the UK.

In general, the other coefficients were significant, with anticipated signs. In particular, the price coefficient was significant and negative. There was a risk that the estimated price coefficient could be biased, as consumers who are heavy Internet users tend to choose more expensive FttH tariffs rather than slower and cheaper DSL tariffs. We were able to mitigate this problem to some extent by estimating a mixed logit model and allowing for consumer-specific price sensitivity. We observed that consumers differ with respect to price responsiveness as the standard deviation on the price coefficient is significant for the first and third estimations.

The valuation of the contract length is different for triple play and quadruple play tariffs. For triple play tariffs, consumers have a negative valuation of 12-month contracts but they positively value 24-month contracts relative to no commitment. This positive valuation may be due to the fact that these contracts are targeted at businesses and self-employed consumers and include tailored features such as dedicated professional portals, data storage, a fixed IP address and so on. For quadruple play tariffs, consumers have a negative valuation of 12-month contracts relative to no commitment, while the coefficient on 24-month is insignificant. Moreover, consumers have a negative valuation of PSTN as a component of triple play offers. Next, quadruple play tariffs with a handset subsidy are valued less on average. In practice, purchasing a subsidized handset, which customers pay for every month throughout their contract period, is more expensive than purchasing a handset without a subsidy. Finally, tariffs with unlimited phone calls are valued more highly, as are tariffs with higher mobile data allowances.

We found that consumers face significant switching costs between tariffs, which increase when

[18] As reported in Table 6, the proportion of FttH connections in the time period we covered rose from 21% to 29%, which represents a 38% increase. This indicates that there is a significant increase in the popularity of FttH connections, which in our model is explained by a rapidly increasing valuation of FttH connections over time. Still, the percentage increase in the valuation of FttH connections by consumers is well above the percentage increase in the proportion of FttH connections. As suggested by our model, this is because even though the valuation of FttH connections increased over time, many consumers did not switch from DSL connections due to high switching costs.

the remaining commitment period is longer. These switching costs may be due to transaction costs, uncertainty and a lack of information about other tariff plans. Moreover, there are additional switching costs between technologies, from DSL to FttH and the other way around, which in absolute values are much higher than switching costs between tariffs. As we discussed earlier, the additional switching cost may stem from the fact that an appointment with a technician is required to set up the initial fiber connection. As shown in Table 3, some consumers switch back to DSL.[19] Switching costs from FttH to DSL tariffs are also much higher than between tariffs based on the same technology. We also observed that consumers have different switching costs since the standard deviation on the switching costs coefficient is significant for all three estimations.

We also estimated two additional model specifications, which we have not reported in the paper due to space constraints.[20] In the first specification, we interacted technology dummies and switching costs with a dummy variable indicating the presence of a cable operator in a municipality. We found that the presence of cable broadband reduces the valuation of both DSL and FttH technologies. This may be due to a higher valuation of the outside option in these geographic areas since consumers living there can get better deals in terms of connection speed and other services when they leave our operator. In addition, we find that costs for switching to FttH significantly decrease in these areas, which may be due to intense marketing campaigns. Our operator intensively promoted FttH to DSL consumers to preempt them from leaving to a cable operator. These marketing campaigns make consumers better informed about the availability and benefits which fiber brings in terms of higher speed. The other model estimates remain unchanged.

In the second specification, we used selected socio-economic characteristics of municipalities in which consumers reside to control for consumer preferences and needs. In the consumer-level dataset there are no observable individual characteristics which could influence the valuation of tariff attributes because such information is confidential. Instead, we can approximate these

[19] As suggested by industry experts, this may be due to dissatisfaction with FttH connections resulting from noisy modems or aesthetic reasons.

[20] We can make these results available upon request.

characteristics using municipality-level statistics on: (i) average income; (ii) the unemployment rate; (iii) the proportion of the population who have passed their baccalaureate; and (iv) the proportion of the population with a university degree. These variables were interacted with an FttH speed variable in Model II. We found that income and the proportion of the population with a university degree are insignificant, while unemployment has a significant and negative impact and the proportion of the population who have passed their baccalaureate has a significant and positive impact. This implies that consumers living in municipalities with a higher unemployment rate are less likely to adopt FttH services and consumers living in municipalities with a higher proportion of the population who have passed their baccalaureate are more likely to adopt FttH services. These results are reasonable and suggest that unemployment and lower levels of educational attainment reduce the value derived from having an FttH connection and the probability of adopting it. The other model estimates also remain unchanged.

5.1 Counterfactual Simulations

There is an ongoing debate on how to encourage firms to develop fiber networks, in which one of the key issues is the transition from DSL and FttH technology. We used the model to conduct a series of counterfactual simulations to contribute to this debate. First, we assessed the role of switching costs in the transition process. The shares of FttH were predicted by setting different switching costs to zero and freezing prices and speeds. Second, we analyzed the role of connection speeds in the presence and absence of switching costs. For these two cases, we predicted shares of FttH for different DSL connection speeds in the range between 1 Mbps and 8 Mbps. We also predicted FttH shares for DSL connection speeds of 50 Mbps, which is the highest speed achievable using VDSL technology.[21] Third, we analyzed the role of price differences between DSL and FttH tariffs for technology transition.

In the first counterfactual simulation shown in Table 6, we assumed that there were no additional switching costs to FttH technology by setting their coefficients to zero. In the second

[21] This counterfactual scenario is an unrealistic, extreme case because VDSL connections with such a speed are only available to consumers who live very close to the exchange. For technical reasons, most consumers cannot get VDSL connections at all.

counterfactual simulation, we assumed that there were no switching costs between tariffs but there were additional switching costs between technologies. In the third counterfactual, we assumed that there were no switching costs at all. In the current base case, as of December 2014, the proportion of FttH connections in the sample of consumers is 29%. The penetration of FttH increased to 54% in the first counterfactual, stayed at 29% in the second counterfactual and increased to 91% in the third counterfactual. The average consumer surplus increased by 10.5 euros in the first case, 6.2 euros in the second case and 38.2 euros in the third case. Based on these estimates we can conclude that switching costs between technologies have the biggest impact on slowing down the transition from DSL to FttH. Switching costs between tariffs also play a role but only in combination with switching costs between technologies.

Next, we simulated the proportions of FttH connections when the speed of all DSL connections is downgraded or upgraded in the presence of switching costs. The possible DSL speeds range between 1 and 8 Mbps. Table 4 shows that most DSL consumers have access to a speed of 5 Mbps and above. As shown in Table 6, in December 2014, compared to the base case, the proportion of FttH connections would not change for the speed of all DSL connections ranging between 1 and 8 Mbps. Even if the speed of all DSL connections increased to 50 Mbps, the proportion of FttH connections would remain unchanged. As shown in Table 7, reducing the DSL speed to 1 Mbps would cause an average loss in consumer surplus of 3.1 euros, increasing the DSL speed to 8 Mbps would result in an average gain in consumer surplus of 1.6 euros and increasing the DSL speed to 50 Mbps would result in an average gain in consumer surplus of 21.1 euros. On this basis, we can conclude that changes in the speed of DSL connections in the presence of switching costs have no effect on the adoption of FttH technology but offering consumers higher speeds increases their welfare.

High switching costs seem to be the reason why DSL speed has no effect on FttH adoption. Thus, we repeated the counterfactual simulations, in which we changed the speed of all DSL connections, but we also set all switching costs to zero. In the absence of switching costs, the proportion of FttH connections remained almost unchanged at 91% when the speed of all DSL connections varied between 1 Mbps and 8 Mbps. But the proportion of FttH connections decreased by 14 percentage points, when the speed of all DSL connections increased to 50 Mbps.

At the same time, the average consumer surplus in the absence of switching costs with a DSL speed of 1 Mbps is lower than the average consumer surplus in the benchmark case without switching costs by about (37.7 - 38.2) = -0.5 euros. For DSL speeds of 8 Mbps there is an average gain in consumer surplus of (38.6 - 38.2) = 0.5 euros, and for DSL speeds of 50 Mbps there is a gain of (44.6 - 38.2) = 6.4 euros. We can conclude that upgrading DSL to VDSL technology slows down FttH adoption but to a much lesser extent than switching costs between technologies.

Finally, we analyzed how price differences between DSL and FttH tariffs influence the proportion of FttH connections. The operator currently charges a 5-euros premium on FttH tariffs, as compared to equivalent DSL tariffs. We found that if the prices of FttH tariffs were 5 euros lower, in the presence of switching costs the proportion of FttH connections would remain unchanged at 29%. This is because the high switching costs would discourage current DSL users from switching to FttH technology. Therefore, the gain in consumer surplus is 5 euros for FttH users and zero for DSL users, which in the last month of our data gives an average of 1.4 euros. In the absence of all switching costs, the proportion of FttH connections would increase by 64 percentage points to 93%. At the same time, the average gain in consumer surplus would be (42.6 - 38.2) = 4.4 euros, as compared to the benchmark case without switching costs. Thus, matching prices of FttH and DSL tariffs increases the share of FttH connections by only 2 percentage points relative to the benchmark case. We can conclude that the price difference does not slow down transition from DSL to FttH technology. In fact, the premium of 5 euros paid by consumers for an FttH connection makes it attractive relative to the much slower DSL connection, which reflects the operator's strategy to stimulate the technology transition.

6 Conclusions

In this paper, we focused on demand factors which may slow down the adoption of FttH broadband technology. These factors are consumer switching costs incurred when switching between tariffs and technologies and the valuation of connection speeds on DSL and FttH technologies. We analyzed the impact of these factors on FttH adoption by estimating a mixed logit model based on monthly data on tariff choices made by customers of a single European telecommunications operator between January and December 2014. Our analysis shows that there are significant switching costs when changing tariffs and technologies. In particular, there are high switching costs from DSL to FttH technology which slow down the transition process. These costs may be due to the time and effort needed to set up the initial fiber connection. In particular, the consumer must schedule an appointment to have a technician visit their home to set up the connection. Switching costs when changing tariffs, which may be due to transaction costs and uncertainty, also play a role but in combination with technology switching costs. Thus, even when operators deploy fiber networks, consumer take-up of FttH connections may be slow due to switching costs.

Furthermore, we found that the valuation of DSL speeds in the range of 1 to 8 Mbps is very similar. Surprisingly, the valuation of an FttH speed of 100 Mbps was initially not much higher than the valuation of DSL speeds of 1 or 8 Mbps but it increased quickly over time. In February 2014, the second month in our data set, the valuation of an FttH speed of 100 Mbps was 2.9% higher than the valuation of a DSL speed of 8 Mbps and 7% higher than the valuation of a DSL speed of 1 Mbps. This relatively small difference in valuations may be explained by the fact that consumers' basic Internet needs, including browsing, emailing, reading news, shopping and even watching videos online can be satisfied with connection speeds below 8 Mbps. In December 2014, the last month in our data set, the valuation of an FttH connection with a speed of 100 Mbps was 59% higher than the valuation of a DSL speed of 8 Mbps and 66% higher than the valuation of a DSL speed of 1 Mbps. The increasing valuation over time may reflect a growing need for high speed connections due to the availability of new online services.

With regard to the potential impact of upgrading DSL lines to VDSL or ADSL+ technologies with speeds of 8 to 50 Mbps on the transition to FttH technology, we found that in the presence of switching costs, upgrading all DSL connections to 50 Mbps, the highest speed achievable with VDSL technology, had no impact on the share of FttH technology. Only in the absence of switching costs, which is unlikely to occur in reality, would the adoption of FttH technology be slowed by upgrading all DSL lines. But given that a speed of 50 Mbps can be achieved only on a relatively small number of copper connections, the impact on the technology transition is minor. At the same time, consumers would immediately benefit from increased connection speeds, which is reflected in the higher consumer surplus.

Furthermore, we found that the current pricing of DSL and FttH services is not slowing the transition process. The premium of 5 euros paid by consumers for an FttH connection makes it attractive relative to a much slower DSL connection. This relatively small premium reflects the operator's strategy to stimulate the technology transition.

Our findings show that if the objectives of the Digital Agenda for Europe are to be achieved, consumer switching costs, particularly when changing tariffs and technologies, must be reduced. While consumers typically do not pay for the installation of fiber technology, they may still need to be offered monetary or other rewards to mitigate the opportunity cost of the time spent scheduling an appointment with a technician and other transaction costs. Moreover, it seems that only after getting high speed Internet connection, consumers may be convinced that speed of 100 Mbps or above can improve their Internet experience and enable them to access new online services.

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Appendix

Table 1: Descriptive statistics: old and new tariffs

Old tariffs					
Variable	Mean	Std. Dev.	Min.	Max.	N
Monthly fee (euros/m)	62.16	25.67	21	141	122
Triple DSL	0.39	0.49	0	1	122
Triple FttH	0.07	0.26	0	1	122
Quadruple DSL	0.34	0.48	0	1	122
Quadruple FttH	0.20	0.40	0	1	122
Handset subsidy	0.32	0.47	0	1	122
Unlimited voice	0.23	0.42	0	1	122
Mobile data allowance (GB)	0.66	1.00	0	6	122
PSTN line	0.14	0.35	0	1	122
New tariffs					
Variable	Mean	Std. Dev.	Min.	Max.	N
Monthly fee (Euros/m)	62.96	26.53	10	147	228
Triple DSL	0.33	0.47	0	1	228
Triple FttH	0.05	0.21	0	1	228
Quadruple DSL	0.35	0.48	0	1	228
Quadruple FttH	0.26	0.44	0	1	228
Handset subsidy	0.47	0.50	0	1	228
Unlimited voice	0.43	0.50	0	1	228
Mobile data allowance (GB)	1.62	2.53	0	10	228
PSTN line	0.14	0.35	0	1	228

Table 2: Number of consumers switching tariffs between January and December 2014

Switches	Consumers	%
0	56,452	60%
1	30,500	32%
2	6,242	7%
3	1,023	1%
4	149	0%
5	21	0%
6	1	0%
Total	94,388	100%

Table 3: Number of switches between types of tariffs between January and December 2014

From/To	Triple DSL	Quadruple DSL	Triple FttH	Quadruple FttH	Leaving
Triple DSL	11,508	2,173	6,873	616	562
Quadruple DSL	27	8,486	21	5,195	36
Triple FttH	1,033	9	2,878	2,041	213
Quadruple FttH	12	596	12	5,345	6
New consumers	191	79	405	117	0

Table 4: Copper line loss

Copper line loss	Basic DSL speed	Consumers
60 dB - 75 dB	$<$ 1 Mbps	1,006
45 dB - 60 dB	2 Mbps	6,236
30 dB - 45 dB	5 Mbps	14,164
15 dB - 30 dB	7 Mbps	23,952
$<$ 15dB	8 Mb/s	13,097
		58,455

Table 5: Estimation results

	Model I	Model II	
Variable	Est.	Est.	Time
Price	-0.070***	-0.056***	
	(0.001)	(0.001)	
Price SD	0.025***	0.020***	
	(0.000)	(0.000)	
Switching	-3.234***	-3.423***	
	(0.013)	(0.016)	
Switching SD	1.194***	1.127***	
	(0.015)	(0.018)	
Switching to FttH	-10.836***	-10.126***	
	(0.215)	(0.256)	
Switching to DSL	-3.923***	-4.609***	
	(0.232)	(0.413)	
Switching commitment	-0.131***	-0.125***	
	(0.001)	(0.001)	
Leaving commitment	-0.078***	-0.073***	
	(0.007)	(0.009)	
Contract 12 TP	-0.383***	-0.367***	
	(0.013)	(0.016)	
Contract 24 TP	6.083***	5.131***	
	(0.035)	(0.040)	
Contract 12 QP	-1.081***	-2.756***	
	(0.055)	(0.048)	
Contract 24 QP	-0.136**	-1.666***	
	(0.065)	(0.065)	
Handset subsidy	0.208***	-0.009	
	(0.047)	(0.058)	
Unlimited voice	1.477***	0.206***	
	(0.032)	(0.028)	
Mobile data	0.371***	0.311***	
	(0.006)	(0.008)	
PSTN line	-0.665***	-0.475***	
	(0.015)	(0.017)	
Triple DSL	10.305***		
	(0.093)		
Quadruple DSL	7.485***		
	(0.101)		
Triple FttH	10.651***		
	(0.098)		
Quadruple FttH	7.059***		
	(0.108)		
Time DSL	-0.000		
	(0.011)		
Time FttH	0.516***		
	(0.013)		
DSL speed 1 Mbps		9.376***	-0.013
		(0.309)	(0.046)
DSL speed 2 Mbps		9.684***	-0.012
		(0.160)	(0.023)
DSL speed 5 Mbps		9.577***	0.011
		(0.131)	(0.018)
DSL speed 7 Mbps		9.581***	0.034**
		(0.121)	(0.016)
DSL speed 8 Mbps		9.750***	0.006
		(0.133)	(0.018)
FttH speed 100 Mbps		8.929***	0.551***
		(0.118)	(0.016)
Observations	3,998,727	2,483,988	
LL	-114,136	-77,574	

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

Table 6: Share of FttH subscriptions

Month	(0) Current situation	(1) No tech SC	(2) No tariff SC	(3) No SC	(4) 50 Mbps with SC	(5) 50 Mbps no SC	(6) 1 Mbps with SC	(7) 1 Mbps no SC	(8) 8 Mbps with SC	(9) 8 Mbps no SC	(10) −5 Euro with SC	(11) −5 Euro no SC
2	21%	21%	23%	23%	20%	14%	21%	24%	21%	22%	21%	24%
3	21%	21%	20%	28%	21%	17%	21%	29%	21%	28%	21%	30%
4	21%	22%	21%	32%	21%	22%	21%	33%	21%	31%	21%	33%
5	22%	23%	22%	38%	21%	28%	21%	41%	21%	37%	21%	41%
6	22%	25%	23%	48%	22%	31%	22%	53%	22%	46%	22%	54%
7	23%	28%	23%	55%	23%	34%	23%	59%	23%	53%	23%	59%
8	24%	34%	24%	72%	23%	41%	24%	76%	24%	70%	24%	77%
9	25%	36%	25%	74%	24%	46%	25%	76%	25%	72%	25%	77%
10	26%	38%	26%	80%	26%	55%	26%	82%	26%	79%	26%	82%
11	27%	43%	28%	86%	27%	67%	28%	88%	28%	85%	28%	88%
12	29%	54%	29%	91%	29%	77%	29%	92%	29%	90%	29%	93%

Share of FttH subscriptions in: (0) current situation; (1) without switching costs to FttH technology; (2) without tariff switching costs; (3) without all switching costs; (4) DSL speed upgraded to 50 Mbps; (5) DSL speed upgraded to 50 Mbps and no switching costs; (6) DSL speed degraded to 1 Mbps; (7) DSL speed degraded to 1 Mbps and no switching costs; (8) DSL speed upgraded to 8 Mbps; (9) DSL speed upgraded to 8 Mbps and no switching costs; (10) FttH price lowered by 5 Euros; (11) FttH price lowered by 5 Euros and no switching costs.

Table 7: Changes in average consumer surplus in Euros

Month	(1) No tech SC	(2) No tariff SC	(3) No SC	(4) 50 Mbps with SC	(5) 50 Mbps no SC	(6) 1 Mbps with SC	(7) 1 Mbps no SC	(8) 8 Mbps with SC	(9) 8 Mbps no SC	(10) −5 Euro with SC	(11) −5 Euro no SC
2	0.0	-7.0	-7.0	-23.7	-30.8	3.5	-3.7	-1.7	-8.7	-1.1	-8.2
3	-0.4	-6.3	-9.2	-23.5	-31.6	3.5	-6.2	-1.7	-10.8	-1.0	-10.8
4	-0.6	-5.8	-10.1	-23.4	-31.2	3.5	-7.3	-1.7	-11.5	-1.1	-11.9
5	-1.0	-6.1	-12.5	-23.3	-32.0	3.5	-10.0	-1.7	-13.8	-1.1	-14.6
6	-1.5	-6.3	-14.9	-23.1	-32.8	3.4	-12.7	-1.7	-16.1	-1.1	-17.5
7	-2.1	-6.5	-17.1	-22.9	-33.6	3.4	-15.1	-1.7	-18.1	-1.2	-19.8
8	-3.5	-6.2	-22.3	-22.6	-35.7	3.4	-20.8	-1.7	-23.1	-1.2	-25.6
9	-4.0	-6.3	-23.3	-22.3	-36.1	3.3	-21.9	-1.6	-24.1	-1.2	-26.7
10	-5.2	-6.6	-26.8	-21.9	-37.7	3.3	-25.7	-1.6	-27.4	-1.3	-30.5
11	-7.2	-6.3	-31.9	-21.5	-40.4	3.2	-31.1	-1.6	-32.4	-1.4	-36.0
12	-10.5	-6.2	-38.2	-21.1	-44.6	3.1	-37.7	-1.6	-38.6	-1.4	-42.6

Change in average consumer surplus relative to current situation: (1) without switching costs to FttH technology; (2) without tariff switching costs; (3) without all switching costs; (4) DSL speed upgraded to 50 Mbps; (5) DSL speed upgraded to 50 Mbps and no switching costs; (6) DSL speed degraded to 1 Mbps; (7) DSL speed degraded to 1 Mbps and no switching costs; (8) DSL speed upgraded to 8 Mbps; (9) DSL speed upgraded to 8 Mbps and no switching costs; (10) FttH price lowered by 5 Euros; (11) FttH price lowered by 5 Euros and no switching costs.