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Subscription Choices and Switching Costs in Mobile Telephony*

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Abstract

In this article, we estimate the price elasticities of demand for subscription and consumer switching costs for mobile telephony. We use a panel of Portuguese consumer level data to estimate a series of multinomial and mixed logit models. The demand for subscription is elastic. Switching costs are large. We use the structural model to perform several policy exercises. Switching costs and brand preferences are shown to be important elements of the market structure of mobile telephony. Price mediated network effects seem to be relatively less important.

Key Words: *Mobile Telephony, Switching Costs, Mixed Logit*

JEL Classification: L13, L43, L93

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1 Introduction

In this article, we estimate the price elasticities of demand for subscription and consumer switching costs for mobile telephony. Our data set consists of a rich panel, based on monthly invoices, of a representative group of 800 Portuguese consumers of mobile telephony services, between April 2003 and March 2004. We estimate several multinomial logit and mixed logit models.

Heckman (1981) distinguishes between true state dependency and spurious state dependency. True state dependence is a consequence of all observable factors, which include switching costs. Spurious state-dependence results from persistent heterogeneity in the preferences for brands. Consumers may continue buying the same product because it fits better their individual tastes. Hence, the parameters that represent switching costs may be biased if spurious state dependence is ignored. We account for spurious state dependence by estimating mixed logit models for panel data.[1]

The Portuguese mobile telephony industry, discussed in the next Section, consists of three firms: *Tmn*, *Vodafone*, and *Optimus*, with revenue market shares in 2005 of 50%, 37%, and 13%, respectively.

The demand for subscription is elastic with respect to price. The price elasticities vary substantially across firms and their consumers. The own-price elasticity of *Tmn* has a mean of −1.65, and a standard deviation of 2.89. The own-price elasticity of *Vodafone* has a mean of −2.10, and a standard deviation of 2.64. Finally, the own-price elasticity of *Optimus* has a mean of −2.33, and a standard deviation of 2.57.

We use the structural model to perform several policy exercises that illustrate the importance of switching costs for the market structure of mobile telephony, and evaluate their impact on the consumer welfare. If switching costs were reduced to zero, the annual consumer surplus would

[1] There is a large body of empirical studies which try to separate true and spurious state dependence. Among studies specifically on switching costs, Chen and Forman (2003) suggest two strategies to separate switching costs from spurious state dependence. They employ an instrumental variable approach and mixed logit estimation, and find high switching costs in the market for routers and switches. Goldfarb (2003) measures loyalty for Internet portals controlling for household-specific heterogeneity by estimating a separate regression for each household. Shum (2004) and Grzybowski (2007) accommodate unobserved heterogeneity via random effects.

increase by 44.7%. Switching costs and brand preferences are shown to be important elements of the market structure of mobile telephony. Price mediated network effects seem to be relatively less important.

There is a large body of literature on the estimation of the demand for telecommunications services using detailed information on usage patterns for fixed and mobile telephony. These studies estimate mainly price elasticities of demand for connection and network originated calls: local, long distance, international and fixed-to-mobile, mobile-to-mobile, etc.[2] Few studies estimate switching costs in the telecommunications industry. This shortage is due to the lack of data on the purchase history of individuals. For instance, Knittel (1997) analyzes the changes in prices for long distance telephone calls in the U.S. after the divestiture of AT&T in 1984, and explains price rigidity through search and switching costs. Epling (2002) studies competition in the long distance telephony market in the U.S. after 1996. She finds evidence of the heterogeneity in subscriber switching costs, and that consumers with high switching costs pay higher prices. Viard (2005) studies the impact of the introduction of number portability on prices for toll-free numbers in the U.S. He finds that when firms cannot discriminate between old locked-in consumers and new ones, switching costs may have an ambiguous effect on prices. Grzybowski (2007) uses a mixed logit model to estimate firm-specific switching costs in mobile telephony in the UK. He finds that both switching costs and persistent tastes lead to state-dependent choices. Finally, 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

[2]For instance, Bloch et al. (1993) use data on a sample of Australian households to estimate price elasticities of demand for calls on fixed networks. Mitchell et al. (1983); Train (1993); Martins-Filho and Mayo (1993) and Bidwell et al. (1995) estimate demand for calls using data on the U.S. market. Ben-Akiva et al. (1987) analyze choices of local telephone service plans using nested logit model. Kridel et al. (2001) analyze how customers select carriers for long distance for the intraLATA market using detailed call information from invoices of residential consumers. Rodini et al. (2002) estimate substitutability of fixed and mobile services for telecommunications access, using data of U.S. households. Heitfield and Levy (2001) use billing information and demographic data to analyze joint distribution of the number and the duration of calls. They estimate a hazard model for the duration of calls and find that the demand for duration is inelastic with respect to price. See also the report of the New Zealand Commerce Commission (2003) for a summary of related studies.

optional plans and plan characteristics plays a role in the consumer switching decision.[3]

The remainder of the article is organized as follows. Section 2 presents briefly the Portuguese mobile telecommunications industry. Section 3 presents the econometric framework. Section 4 presents and discusses the estimation results. Section 5 concludes.

2 Overview of the Industry

In Portugal, the firm associated with the telecommunications incumbent, *Tmn*, started its activity in 1989, with the analogue technology *C-450*. In 1991, the sectorial regulator, *ICP-ANACOM*, assigned two licenses to operate the digital technology *GSM 900*. One of the licenses was assigned to *Tmn*. The other license was assigned to the entrant *Vodafone*. *Tmn* introduced pre-paid cards in 1995 for the first time worldwide. In 1997, the sectorial regulator assigned three licenses to operate the digital technology *GSM 1800*. Two licenses were assigned to *Tmn* and *Vodafone*. A third license was assigned to the entrant *Optimus*, which was also granted a license to operate *GSM 900*.

At the end of the nineties, the legislation of the *EU* imposed the full liberalization of the telecommunications industry. The liberalization affected essentially fixed line services. After 1998, any firm licensed by the sectorial regulator could offer fixed telephony services, either through direct access based on their own infrastructures, or through indirect access, available for all types of calls. In Portugal the liberalization took effect in 2000.

In 2001, *ICP-ANACOM* assigned four licences to operate the *3G* technology *IMT2000/UMTS*. Three licenses were assigned to *Tmn*, *Vodafone*, and *Optimus*. A fourth license was assigned to the entrant *Oniway*, which was not granted a license to operate *GSM*, and never operated. Service began in 2001.

After its inception in 1989, the Portuguese mobile telephony industry had a fast diffusion,

[3] A few other studies use individual level data to estimate switching costs in different industries. Chen and Hitt (2002) estimate the magnitude of switching costs and brand loyalty in the online brokerage industry. Chen and Forman (2003) find high switching costs in the market for routers and switches. Dube et al. (2006) calibrate a model of dynamic price competition with heterogeneous consumers and imperfect lock-in using data on frequently purchased packaged goods. Goldfarb (2003) measures loyalty for Internet portals. Shum (2004) estimates switching costs in the breakfast cereal industry.

analyzed in Pereira and Pernías (2006) and Pereira and Ribeiro (2006). In 2005 the penetration rate of mobile telephony in Portugal was 110%. After entering the market in 1992, *Vodafone* gained revenue market share rapidly. During the duopoly period, i.e., from 1992 to 1997, *Tmn* and *Vodafone* essentially shared the market. The entry of *Optimus* led to an asymmetric split of the market.

3 Econometric Model

In this section, we present the econometric model.

3.1 Utility of Mobile Telephony Subscription

We index consumers with subscript $i = 1, ..., N$, index firms with subscript $j = 1, ..., J$, and index time with subscript $t = 1, ..., T$. Each firm offers one product. Denote by p_{ijt}, the cost for individual i of consuming alternative j in period t, denote by r_j, a dummy variable for firm j, and denote by z_{it}, a vector of characteristics of consumer i in period t. The consumer characteristics are: **(i)** the age below 30 years, **(ii)** the age between 30 and 50 years, **(iii)** the gender, **(iv)** the residence in the Lisbon region, and **(iv)** the social class. Denote by s_{ijt}, a dummy variable that takes value 0 if consumer i chooses in period t the same alternative j he chose in period $t-1$, and takes value 1 otherwise. This variable accounts for switching costs, and its coefficient is interpreted as the disutility of changing of provider.

Before subscribing to a firm, consumers form expectations about the number of calls and messages.[4] We assume that a consumer's expected calling pattern is independent of the firm to which he subscribes. This assumption is justifiable because the demand for usage is inelastic.[5]

[4]Actually, consumers make three interrelated decisions. First, they choose a firm. Second, they choose the number of calls and the number of messages. Third, they choose the duration of the calls. Because of missing information on tariffs, we cannot link the demands for calls and messages and the demand for network operator. However, even in the presence of information on tariffs, the modeling of demand would be very complicated due to different services available and prices varying by time and destination of calls.

[5]Grzybowski and Pereira (2007a) estimated a price elasticity of demand for mobile telephone calls of -0.38, and Grzybowski and Pereira (2007b) estimated a price elasticity of demand for the duration of mobile telephone calls of -0.2.

Besides, the price differences across firms are relatively small.

After forming expectations about the cost of using mobile services, a consumer chooses the firm to which he subscribes. Consumer i derives utility from alternative j in period t given by:

$$U_{ijt}(p_{ijt}, r_j, z_{it}, s_{it}, \xi_{ij}; \theta) = V_{ijt}(p_{ijt}, r_j, z_{it}, s_{ijt}, \xi_{ij}; \theta) + \epsilon_{ijt},$$

where ξ_{ij} is an unobservable individual heterogeneity component, and ϵ_{ijt} is a stochastic error term, and θ is a vector of parameters to be estimated.[6] We assume additionally that:

$$V_{ijt}(p_{ijt}, r_j, z_{it}, s_{it}, \xi_{ij}; \theta) := r_j - \alpha p_{ijt} + \beta_j z_{it} + \gamma s_{it} + \xi_{ij},$$

where α is the price coefficient, i.e., the negative of the marginal utility of income, β is the vector of the coefficients of the consumer characteristics, γ is the coefficient of the dummy variable s_{ijt}.

Variable ϵ_{ijt} is identically and independently distributed across individuals, alternatives, and periods, and follows a Type I extreme value distribution, with a scale parameter σ_ϵ. Let $\xi := (\xi_{i1}, \xi_{i2})$.[7] Variable ξ is identically and independently distributed across individuals, and follows a joint-normal distribution with mean μ and variance-covariance matrix Σ, whose density function is denoted by $f(\cdot)$. In addition, the error term, ϵ_{ijt}, and the unobservable individual heterogeneity component, ξ_{ij}, are uncorrelated with the explanatory variables, $(p_{ijt}, r_j, z_{it}, s_{ijt})$.

3.2 Choice Probabilities

The assumptions on ϵ_{ijt} imply that conditional on the individual specific variable, ξ, the choice probability of each firm is given by the logit formula. Thus, the conditional probability of consumer i selecting alternative j in period t is:

$$P_{ijt}(\xi) := \Pr[j | p_{ijt}, \cdot, \xi] = \frac{\exp(V_{ijt}(\xi_{ij}))}{\sum_{j \in J} \exp(V_{ikt}(\xi_{ik}))}.$$

The unconditional choice probability is given by:

$$\tilde{P}_{ijt} := \int_\xi P_{ijt}(\xi) f(\xi) d\xi. \tag{1}$$

[6] The other potential choice determinants, such as the coverage and reception quality, are assumed to be constant throughout the time of this study.

[7] We normalize the utility of one alternative to zero.

This specification can be generalized to the case of repeated choices. Assuming that the coefficients are constant over choices, but vary across consumers, the unconditional probability (1) for a sequence of choices is given by:[8]

$$\tilde{P}_{ijt} := \int_{\xi} \prod_{t} P_{ijt}(\xi) f(\xi) d\xi. \tag{2}$$

3.3 Demand Elasticities

Denote by ε_{ijkt}, the elasticity of demand of product j with respect to the price of product k for consumer i in period t:

$$\varepsilon_{ijkt} := \frac{\partial P_{ijt}}{\partial p_{ikt}} \frac{p_{ikt}}{P_{ijt}}.$$

In the multinomial logit model, the partial derivative is given by

$$\frac{\partial P_{ijt}}{\partial p_{ikt}} = \begin{cases} -\alpha P_{ijt}(1 - P_{ijt}) & \text{if k=j} \\ \alpha P_{ijt} P_{ikt} & \text{otherwise,} \end{cases}$$

which implies the following elasticities:

$$\varepsilon_{ijkt} = \begin{cases} -\alpha p_{ijt}(1 - P_{ijt}) & \text{if k=j} \\ \alpha p_{ikt} P_{ikt} & \text{otherwise.} \end{cases}$$

In the mixed logit model, the partial derivatives of the choice probabilities are given by:

$$\frac{\partial \tilde{P}_{ijt}}{\partial p_{ikt}} = \begin{cases} -\alpha \int_{\xi} P_{ijt}(\xi)(1 - P_{ijt}(\xi)) f(\xi) d\xi & \text{if k=j} \\ \alpha \int_{\xi} P_{ijt}(\xi) P_{ikt}(\xi) f(\xi) d\xi & \text{otherwise,} \end{cases}$$

where $P_{ijt}(\xi) = \frac{\exp(V_{ijt}(\xi_{ij}))}{\sum_{j \in J} \exp(V_{ikt}(\xi_{ik}))}$, and the elasticities are obtained analogously.

3.4 Consumer Surplus

Denote by $V^0_{ijt}(\xi)$ and $V^1_{ijt}(\xi)$, the utility levels before and after a price increase, respectively. The change in consumer welfare caused by a price increase can be represented by the compensating variation. It captures the money amount by which consumers would need to be

[8]Since many consumers did not provide information about bills for the whole period, our panel is unbalanced.

compensated to maintain the same level of utility after a price change (Small and Rosen (1981)). This formula for consumer i is given by:

$$CV_i = \frac{1}{\alpha}\sum_t \int_\xi \Big[ln\Big(\sum_{j \in J} exp(V^1_{ijt}(\xi_{ij})) \Big) - ln\Big(\sum_{j \in J} exp(V^0_{ijt}(\xi_{ij})) \Big) \Big] f(\xi) d\xi. \tag{3}$$

3.5 Estimation Strategy

The utility of *Vodafone* is normalized to zero. Thus, all estimates are interpreted relative to those of *Vodafone*.

In our data set the churn rate is 4% a year. Since few consumers switch of provider, we assume that switching costs are the same across firms.[9]

The identification of the state dependency is based on the comparison of the choices of consumers who subscribed to a given firm in the previous period, with the choices of the consumers who subscribed to the other firms. As discussed in section 4.1, in our data set 62% of consumers subscribe to the cheapest firm for their observed usage pattern. The remaining consumers use more expensive providers due to either: switching costs, uncertainty about the cost of the alternatives, or persistent brand preferences.

We approximate the probabilities in (2) through simulation. First, we draw a vector of values ξ^r from distribution $N(\mu, \Sigma)$, and label it with subscript $r = 1$. Second, given the value of ξ^r, we calculate the logit formula inside the integral in (2). We repeat these two steps R times and calculate the simulated choice probability through the average:

$$\tilde{P}_{ijt} := \frac{1}{R}\sum_{r=1}^{R} \Big[\prod_t \frac{\exp(V_{ijt}(\xi^r_{ij}))}{\sum_{j \in J} \exp(V_{ikt}(\xi^r_{ik}))} \Big].$$

The mixed logit simulated log-likelihood function for a given sequence of choices is given by:

$$\mathcal{L}(\cdot) = \sum_i \log(\tilde{P}_{ijt}).$$

The maximum simulated likelihood estimator is the value of the distribution parameters, (μ, Σ), and the coefficients of the utility function, θ, that maximizes $\mathcal{L}$.

[9] It is possible to estimate firm specific switching costs for a multinomial logit model. These estimates, however, do not vary significantly across firms, and a likelihood ratio test cannot reject the null hypothesis of their equality. For a mixed logit model, firm specific switching costs lead to problems in the identification of the random effects.

To implement the random-effects approach, we assume that: **(i)** the initial choices are exogenous, and **(ii)** the joint distribution of the unobserved effects does not depend on the initial choices. These assumptions ensure that the distribution of the unobserved heterogeneity parameters is invariant to the initial choices. Assuming that the initial conditions are exogenous bias upwards the estimated state dependence, and bias downwards the estimated heterogeneity.[10]

4 Econometric Implementation

In this section, we: **(i)** describe the data, **(ii)** present the estimation results, **(iii)** present the price elasticities of demand, and **(iv)** perform some policy exercises.

4.1 Data

Our data set consists of a micro panel, based on monthly invoices. The information was collected by *Marktest* for mainland Portugal, between April 2003 and March 2004. The panel of 800 households is proportional, segmented by age, 5 social classes and 6 regions.[11] Table 1 shows the information recorded for each communication made by an individual. Calls to mobile networks, calls to fixed networks, and messages account for 95% of the traffic.

[*Table* 1]

[10]The observed choices of the first period depend on of the choices of the earlier periods, which are not observed. Hence, it is not possible to estimate the model for this period. More importantly, it may be expected that the outcome of the initial choices depends on unobserved heterogeneity. The short time period between the first and the last observations in our data set, and the resulting small number of switching consumers makes it difficult to account for endogenous initial conditions. Solutions to the problem of endogenous initial conditions for the dynamic probit model are discussed by Heckman (1981) and Wooldridge (2002). Heckman (1981) proposes approximating the conditional distribution of the initial condition. Wooldridge (2002) suggests to model the distribution of the unobserved effect conditional on the initial value and any exogenous explanatory variables.

[11]The stratification of the sample was based on the 2001 census data from the Portuguese National Statistics Institute. The social class levels are: 1 – High, 2 – Medium/High, 3 – Medium, 4 – Medium/Low, 5 – Low. The regions are: 1 – Greater Lisbon, 2 – Greater OPorto, 3 – Northern Coast, 4 – Central Coast, 5 – Northern Interior, 6 – South.

Table 2 presents the monthly values for our sample of the subscriber market shares.

[$Table$ 2]

Table 3 shows the average monthly invoice values.

[$Table$ 3]

The data set has three limitations. First, there is no information about the tariff plans chosen by the individuals. Second, there is little variation in prices among the clients of each firm, and over time.[12] Third, the data set only samples users of mobile telephony.

[$Table$ 4]

[$Table$ 5]

[$Table$ 6]

For the choice of which firm to subscribe, we need to assign to each individual: **(i)** the cost of using the service to which he subscribes, and **(ii)** the cost of using the alternatives. Because we have no information about the tariff plans chosen by the individuals, we have to infer the price paid by consumers for calls and messages based on the information from the invoices.[13] We compute the cost of using mobile services as follows. First, for all subscribers of a given firm in a given month, we calculate the average per-second price of calling mobile and fixed line numbers at certain times of the day, and of the week, i.e., weekday and weekend, and similarly for sending messages. The values of average prices for 60-seconds calls and for messages at different times of the day, and different days of the week in April 2003 are provided in Table 4. Then, given individual calling patterns, we calculate for each consumer the cost of using the services of different firms. This calculation assumes that all consumers face the same average

[12]Most of the consumers of *Optimus* pay 0.211 cents per minute, without VAT, and almost all of the consumers of *Vodafone* pay 0.238 cents per minute. There is more variation in the per minute prices paid by the consumers of *Tmn*.

[13]The data set does not indicate how much individuals pay for monthly subscription fees. However, in Portugal over 80% of the subscribers have pre-paid cards. Since our sample is composed of residential clients, the percentage of subscribers with pre-paid cards is certainly no smaller.

per-second prices. This is a strong assumption, but common in empirical studies. In fact, we are more precise than usual, by calculating the variation in price over time and destination. The differences in the value of the invoices are determined by the type, length, and timing of the calls and messages. The correlation between the observed values and the computed values of the invoices is 90% or higher, depending on the month and the firm, as shown in Tables 5 and 6. Moreover, 62% of consumers are subscribed to the cheapest firm for their observed usage pattern. This suggests that our procedure is reasonable.

We do not observe individuals who choose not to use mobile services. Hence, we assume that in the period of this study, everybody has access to mobile services. This assumption is justifiable because the penetration rate of mobile telephony in Portugal reached 90% in the second quarter of 2004, and 110% in the fourth quarter of 2005. [14]

We model switching costs through the dependence of the subscription choices of the current period on the subscription choices of the previous period. Thus, for the models where we assume that consumers choose to which firm they subscribe every month, we loose the observations from the first month. For the models where the horizon of the consumers' subscription choices is larger than one month, we loose a larger number of observations. In addition, if there is a gap in the reported invoices, we loose the first observation after this gap.

In the estimation with monthly choices we use $8,015$ observations. The market shares for the whole sample are preserved and represent 50.3%, 33.5%, and 16.2%, for *Tmn*, *Vodafone*, and *Optimus*, respectively.

[14] The European Commission and national competition authorities, in a number of decisions on mobile communications services, used product market definition which excludes fixed communications services. The Commission claimed that mobile communications services cannot be seen as being substitutable to fixed communications services because of the mobility inherent in all mobile services, i.e., mobile numbers are associated with individuals on the move, rather than a fixed location. Such market definition implies that if the prices of mobile telephony services increased, nobody would give up mobile services.

4.2 Basic Estimation Results

We estimated seven models by maximum likelihood.[15] The results are presented in Tables 7 and 8.

[*Table* 7]

In Models 1, 2, 3, and 4, we assume that consumers choose every month to which firm they subscribe. Model 1 is a multinomial logit model without switching costs. The estimates of the price coefficient and the consumer characteristics are significant.

Model 2 is a multinomial logit model with switching costs. Compared with Model 1, Model 2 has a much larger log-likelihood. In addition, the estimate of the price coefficient decreases, but remains significant. Consumer characteristics are non-significant in determining the choice of *Optimus* and *Tmn* compared to *Vodafone*.[16] The estimate of the coefficient of the switching costs dummy variable is negative, relatively large, and highly significant. This suggests that consumers have substantial switching costs. Because few consumers switch of provider, prices and switching costs explain almost perfectly the choice probabilities. However, this specification ignores the presence of unobservable persistent heterogeneity, which may bias the estimates of switching costs.

Model 3 is a mixed logit model with switching costs, and persistent unobserved brand preferences. This specification implies a contemporaneous and an intertemporal dependence of choices. Compared with Model 2, the overall fit improves. The likelihood ratio test rejects the null hypothesis that there is no persistent consumer heterogeneity. The test statistic is $\chi^2 = 12$, which is larger than the critical value for two degrees of freedom $\chi^2(0.01, 2) = 9.21$. In addition, the estimates of the coefficients of prices and the dummy variable for switching costs increase. The estimates of the coefficients of the firm dummy variables are insignificant for both *Optimus* and *Tmn*, but have significant standard deviations. The estimates of the coefficients of the consumer characteristics are insignificant as before. Therefore, the choice probabilities are explained by: switching costs, prices, and persistent unobserved brand preferences.

[15] We used the SAS procedure "proc nlmixed" to estimate the mixed logit models.

[16] The coefficients on consumer characteristics are alternative specific. After the normalization $(\beta_j - \beta_3)\, z$ is estimated, and the coefficient is then interpreted relative to the coefficient of alternative 3.

Model 4 is similar to Model 3, except that it excludes consumer characteristics. The estimate of the coefficient of the firm dummy variable is significant and negative for *Optimus*, and insignificant for *Tmn*. Thus, on average, consumers value equally *Tmn* and *Vodafone*, and value *Tmn* and *Vodafone* relatively more than *Optimus*. However, given the standard deviations, there are consumers with both higher and lower valuations for *Optimus* relative to *Vodafone*, and similarly for *Tmn*.

Table 8 presents the estimates of mixed logit model assuming different choice horizons.

[*Table* 8]

Models 5, 6, and 7 are similar to Model 4, except that the horizon of the subscription choices is two, three, and four months, respectively. The estimates of the coefficient of the dummy variable for switching costs decrease slightly, and the estimates of the price coefficient increase. Thus, if the horizon of the subscription choices increases from one to four months, the demand becomes more elastic with respect to price.

Given the previous discussion, we select Model 4 to conduct our analysis.

4.3 Price Elasticities of Demand

Table 9 presents the own- and cross-price elasticities of demand for the whole sample of individuals.

[*Table* 9]

The own- and cross-price elasticities are large and vary substantially across firms and their consumers. The own-price elasticity of the demand of *Tmn* has a mean of −1.65, a median of −0.05, and a standard deviation of 2.89. If the price of *Tmn* increases 1%, on average, the number of subscribers of *Tmn* decreases 1.65%. The cross-price elasticities of the demand of *Tmn* with respect to the prices of *Vodafone* and *Optimus* are 1.29 and 1.24, respectively. If the price of *Vodafone* increases 1%, on average, the number of subscribers of *Tmn* increases 1.29%. The own-price elasticity of the demand of *Vodafone* has a mean of −2.10, a median of −1.30, and a standard deviation of 2.64. The cross-price elasticities of the demand of *Vodafone* with respect to the prices of *Tmn* and *Optimus* are both 0.97. Finally, the own-price elasticity of the demand of *Optimus* has an average of -2.33, a median of -1.70, and a standard deviation of 2.57. The cross-price elasticities of the demand of *Optimus* with respect to the prices of *Tmn* and *Vodafone* are 0.43 and 0.49, respectively.[17]

Table 10 presents the average marginal effects.

[$Table$ 10]

The marginal effects of changes in prices on the probability of choices are very small, which is due to switching costs being high. Thus, a price increase by one of the firms does not lead to a substantial reallocation of consumers. For instance, if the price of *Tmn* increases by 100%, on average, the probability of a consumer subscribing to *Tmn* decreases 0.048. If the price of *Vodafone* increases 100%, on average, the probability of a consumer subscribing to *Tmn* increases 0.016.

4.4 Some Policy Exercises

Next we perform six policy exercises to illustrate the importance of switching costs for the market structure of mobile telephony, and to evaluate their impact on the consumer welfare. Some of the exercises consist of simulations using the structural model of demand, reported in Table 11. Since the market shares do not change substantially over time, we compute only the average annual market shares.

First, we calculate the impact on the consumer surplus of a price increase, given by (3). If the prices of all firms increase 10%, the annual consumer surplus decreases by 8.76%. If, however, the switching costs are reduced to zero, the annual consumer surplus increases by 44.7%.[18]

[$Table$ 11]

Second, we compute the market shares assuming that the switching costs are equal to 0 for all firms. The market share of *Optimus* increases 10 percentage points, mostly at the expense of *Tmn*, whose market share decreases 8 points. However, *Tmn* still remains with the largest

[17] Grzybowski and Pereira (2006) in the estimation based on industry level data for Portugal between 1999 and 2005 also find that demand for subscriptions is very elastic.

[18] As for the price elasticities, the calculation was conducted for $1,000$ random draws.

market share. This may be due to brand preferences, or to *Tmn* being the cheapest alternative for many consumers, given their usage pattern.

Third, we compute the market shares assuming that for *Tmn* the prices of on-net and off-net calls are the same and equal to the average price of mobile calls. As shown in Table 4, there are substantial differences between the prices of on-net and off-net calls. This may provide *Tmn* with a competitive advantage by creating price-mediated network effects. Because most calls are on-net, the average price of mobile calls for *Tmn* of is close to the price of on-net calls. This implies that *Tmn* is the cheapest firm for many consumers. Consequently, the market shares do not change at all. However, if one assumes in addition that there are no switching costs, the market share of *Tmn* decreases by 2 points more than in the former case.

Fourth, we compute the market shares assuming that switching costs are equal 0 for only one of the firms. It is costless to switch to a given firm, but it remains costly to switch to the other firms.[19] The case where the cost of switching to *Tmn* is 0 involves the largest reallocation of consumers. The market share of *Tmn* increases 22 points, mostly at the expense of *Vodafone*, whose market share decreases 14 points.

Fifth, we compute the market shares assuming that for all consumers, *Tmn* and *Vodafone* have the same cost of mobile services, and set the switching costs to 0 for all firms. The market shares of *Tmn*, *Vodafone*, and *Optimus* are, respectively, 0.37, 0.34, and 0.29. Since consumers value *Tmn* and *Vodafone* equally, this shows that persistence of brand preferences plays an important role in mobile telephony.

Sixth, we compute the market shares assuming that one of firms sets its price to 0, and the switching costs remain at the estimated level. Interestingly, the changes in market shares are smaller than when the cost of switching to the same firms is 0. For instance, if the cost of switching to *Optimus* is 0, while the cost of switching to the other firms remains at the estimated level, the market shares of *Tmn*, *Vodafone*, and *Optimus* are, respectively, 34%, 21% and 45%. If the price of *Optimus* is 0 while the prices of the other firms and the cost of switching remain at the estimated level, the market shares of *Tmn*, *Vodafone*, and *Optimus* are, respectively, 46%, 29% and 25%.

[19] The firm in question may pay consumers the equivalent of their switching costs.

These simulations illustrate three important points. First, switching costs are an important element of the market structure of mobile telephony. Even if firms were to set prices to zero, in the short run, only a relatively small share of consumers would switch of provider. Second, persistent brand preferences are also an important element of the market structure of mobile telephony. Even if the switching costs of all firms where zero, the relative ranking of the firms in terms of market share would remain unchanged. Third, price mediated network effects are less important than switching costs and brand preference in the market structure of mobile telephony.

5 Conclusion

In this article, we estimated the price elasticities of demand for subscription and consumer switching costs for mobile telephony. We used data from a panel of about 800 consumers of mobile services in Portugal between April 2003 and March 2004, and estimated several multinomial and mixed logit models.

Our findings show that the demand for subscription is elastic with respect to price, and that the price elasticities vary substantially across firms and their consumers. Switching costs are very high.

We also performed several policy exercises to illustrate the importance of switching costs for the market structure of mobile telephony, and to evaluate the impact on welfare on the consumer switching costs.

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Tables

Table 1: Information Recorded about Calls

Originating network	*Optimus*, *Tmn*, *Vodafone*
Type of call	international, services, n800, messages *Optimus*, *Tmn*, *Vodafone*, fixed line, others, data
Value	cents without VAT
Date	year/month/day
Time	hour/minute/second

Table 2: Subscriber Market Shares

month	No.	Optimus	Tmn	Vodafone
04.2003	862	0.21	0.49	0.30
05.2003	896	0.21	0.49	0.30
06.2003	895	0.21	0.49	0.30
07.2003	889	0.22	0.47	0.30
08.2003	920	0.21	0.48	0.31
09.2003	940	0.21	0.48	0.31
10.2003	943	0.20	0.48	0.31
11.2003	826	0.12	0.51	0.36
12.2003	858	0.15	0.51	0.33
01.2004	822	0.13	0.51	0.37
02.2004	833	0.14	0.51	0.35
03.2004	904	0.16	0.50	0.34

Table 3: Monthly Average Expenditure in Euros

	Optimus		Tmn		Vodafone	
month	No.	Bill	No.	Bill	No.	Bill
04.2003	181	13.82	422	13.66	259	16.21
05.2003	191	14.97	442	14.02	263	17.83
06.2003	189	15.12	439	12.96	267	19.45
07.2003	199	15.93	421	15.51	269	22.35
08.2003	192	16.73	444	13.65	284	21.07
09.2003	201	15.94	450	14.11	289	21.49
10.2003	190	12.87	457	13.12	296	19.43
11.2003	103	17.86	423	12.89	300	21.21
12.2003	132	14.24	437	15.03	289	22.89
01.2004	104	16.76	420	12.91	298	19.25
02.2004	113	15.06	428	12.78	292	17.56
03.2004	143	14.84	454	13.71	307	17.67

Table 4: Average Prices of 1-minute Calls and Messages in April 2003 (Euros)

Weekday		Optimus	Tmn	Vodafone
0-7	SMS	0.097	0.064	0.047
	fixed	0.210	0.204	0.240
	mobile off-net	0.213	0.407	0.222
	mobile on-net	0.190	0.150	0.218
7-17	SMS	0.097	0.067	0.053
	fixed	0.218	0.233	0.251
	mobile off-net	0.228	0.313	0.255
	mobile on-net	0.190	0.149	0.211
17-0	SMS	0.098	0.069	0.056
	fixed	0.214	0.243	0.233
	mobile off-net	0.226	0.303	0.245
	mobile on-net	0.190	0.151	0.215
Weekend				
0-7	SMS	0.098	0.063	0.058
	fixed	0.210	0.258	0.246
	mobile off-net	0.210	0.240	0.234
	mobile on-net	0.199	0.151	0.238
7-17	SMS	0.098	0.070	0.055
	fixed	0.206	0.217	0.218
	mobile off-net	0.205	0.273	0.221
	mobile on-net	0.197	0.145	0.220
17-0	SMS	0.098	0.072	0.057
	fixed	0.205	0.203	0.204
	mobile off-net	0.209	0.269	0.224
	mobile on-net	0.189	0.147	0.224

Table 5: Average Computed Cost of Alternatives in April 2003 in Euros

Optimus	Mean	Std	Min	Max
observed	13.66	14.24	0.20	84.00
Optimus	13.57	14.18	0.19	82.33
Tmn	16.80	18.08	0.13	96.29
Vodafone	14.44	14.80	0.10	80.14
Tmn				
observed	13.81	12.91	0.16	97.42
Optimus	18.89	19.14	0.41	127.02
Tmn	15.06	14.63	0.30	110.58
Vodafone	19.54	20.45	0.43	135.99
Vodafone				
observed	16.61	23.55	0.23	237.48
Optimus	18.12	25.36	0.22	223.51
Tmn	20.66	30.66	0.21	277.84
Vodafone	17.38	24.45	0.21	220.95

Table 6: Average Computed Cost of Alternatives in April 2003: Correlation Matrix

Optimus	observed	Optimus	Tmn	Vodafone
observed	1.00			
Optimus	0.97	1.00		
Tmn	0.92	0.93	1.00	
Vodafone	0.92	0.94	0.98	1.00
Tmn				
observed	1.00			
Optimus	0.83	1.00		
TMN	0.88	0.97	1.00	
Vodafone	0.82	0.99	0.97	1.00
Vodafone				
observed	1.00			
Optimus	0.89	1.00		
Tmn	0.90	0.98	1.00	
Vodafone	0.92	0.99	0.99	1.00

Table 7: Multinominal Logit and Mixed Logit

	Model 1		Model 2		Model 3		Model 4	
Parameter	Estimate	t	Estimate	t	Estimate	t	Estimate	t
price	-0.478	-42.46	-0.1970	-6.70	-0.2591	-4.31	-0.2161	-5.80
s			-6.2864	-27.65	-8.4788	-8.46	-7.9939	-10.10
Opt dummy	-0.965	-6.43	-0.7861	-0.64	-1.0687	-0.05	-0.8376	-2.65
Opt std					1.8145	3.51	1.7396	4.50
age< 30	0.788	7.45	1.0639	1.42	1.1340	0.36		
age< 50	-0.089	-0.99	0.2840	0.43	0.2448	0.12		
Lisbon	-0.114	-1.21	0.7666	1.07	0.8113	0.14		
male	0.443	5.79	0.2184	0.40	0.2036	0.08		
class A	-1.888	-8.96	-2.8034	-2.01	-3.2645	-0.17		
class B	-0.823	-5.39	-0.4520	-0.36	-0.0852	-0.00		
class C1	-0.857	-5.81	-1.1646	-0.96	-1.3808	-0.07		
class C2	0.003	0.02	0.5360	0.42	1.1746	0.06		
Tmn dummy	-0.096	-0.67	-0.0674	-0.05	-0.3245	-0.01	0.1236	0.41
Tmn std					1.7641	4.02	1.5859	4.00
age< 30	0.364	4.26	0.0651	0.09	0.1642	0.09		
age< 50	0.042	0.58	-0.1116	-0.17	-0.0368	-0.01		
Lisbon	-0.345	-4.66	-0.0626	-0.09	0.1451	0.13		
male	0.300	4.92	0.3058	0.55	0.3338	0.14		
class A	0.018	0.11	0.0566	0.04	-0.5016	-0.02		
class B	0.178	1.23	0.3668	0.28	0.5860	0.02		
class C1	0.167	1.18	-0.1569	-0.12	-0.4422	-0.02		
class C2	0.381	2.58	0.8322	0.61	1.3606	0.05		
LL	-5756		-177		-171		-179	
Obs	8015		8015		8015		8015	
Cragg-Uhler1	0.532		0.8839		0.8840		0.8838	
Cragg-Uhler2	0.599		0.9944		0.9946		0.9943	
Adj.Estrella	0.604		0.9998		0.9998		0.9998	
McFadden LRI	0.346		0.9799		0.9806		0.9796	

Table 8: Mixed Logit for Different Choice Intervals

	Model 4		Model 5		Model 6		Model 7	
Parameter	Estimate	t	Estimate	t	Estimate	t	Estimate	t
price	-0.2161	-5.80	-0.2079	-6.65	-0.2225	-7.90	-0.2456	-7.42
s	-7.9939	-10.10	-7.4926	-9.24	-7.1585	-9.72	-7.1273	-8.35
Opt dummy	-0.8376	-2.65	-0.7077	-2.57	-0.8857	-3.23	-1.0676	-3.44
Opt std	1.7396	4.50	1.7421	4.16	1.7227	4.74	1.6645	3.59
Tmn dummy	0.1236	0.41	0.4152	1.55	0.3928	1.55	0.6106	2.17
Tmn std	1.5859	4.00	1.6729	-4.07	1.6450	-3.80	1.5791	3.13
LL	-179		-240		-253		-210	
Obs	8015		6867		5919		5037	
Cragg-Uhler1	0.8838		0.8808		0.8790		0.8792	
Cragg-Uhler2	0.9943		0.9909		0.9888		0.9891	
Adj.Estrella	0.9998		0.9995		0.9992		0.9992	
McFadden LRI	0.9796		0.9898		0.9611		0.9878	

Table 9: Demand Elasticities: Choices of Network Operators

	Optimus	Tmn	Vodafone
Optimus	-2.33	0.43	0.49
median	-1.70	0.002	0.01
variance	2.57	1.32	1.44
Tmn	1.24	-1.65	1.29
median	0.12	-0.05	0.23
variance	1.99	2.89	2.07
Vodafone	0.97	0.97	-2.10
median	0.01	0.006	-1.30
variance	2.26	2.30	2.64

Table 10: Marginal Effects: Choices of Network Operators

	Optimus	Tmn	Vodafone
Optimus	-0.00051	0.00032	0.00019
median	-0.00022	0.00018	0.00000
variance	0.0011	0.00056	0.00081
Tmn	0.00032	-0.00048	0.00016
median	0.00018	-0.00031	0.00014
variance	0.00056	0.0006	0.00020
Vodafone	0.00019	0.00016	-0.00035
median	0.00000	0.00014	-0.00025
variance	0.00081	0.00020	0.00085

Table 11: Market Shares Simulations

	Optimus	Tmn	Vodafone
observed	0.16	0.50	0.34
s=0 for all	0.26	0.42	0.32
s=0 for all, on-net=off-net for Tmn	0.27	0.40	0.33
s=0 for Optimus	0.45	0.34	0.21
s=0 for Tmn	0.08	0.72	0.20
s=0 for Vodafone	0.07	0.32	0.61
s=0 for all, equal prices for Tmn and Vodafone	0.29	0.37	0.34
price=0 for Optimus	0.25	0.46	0.29
price=0 for Tmn	0.14	0.58	0.28
price=0 for Vodafone	0.14	0.45	0.41