The Complementarity between Calls and Messages in Mobile Telephony*

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July 2007

Abstract

This article estimates the price elasticities of the demand for mobile telephone calls and the demand for messages for Portugal. We use a panel of individual level data. In order to account for the unobserved individual heterogeneity and for the data censoring, we estimate a Tobit model for panel data with individual random effects. The demand for calls and the demand for messages are inelastic. Calls and messages are complements.

Key Words: *Mobile Telephony, Price Elasticities, SMS, Complementarity*

JEL Classification: L13, L43, L93

*The opinions expressed in this article reflect only the authors' views, and in no way bind the institutions to which they are affiliated.

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1 Introduction

Short Message Services, *SMS*, are until now the most successful data services on mobile telephones.[1] They account for $15 - 20\%$ of the revenues of many mobile telephony firms, and for up to 95% of data revenues. Telecommunications sectorial regulators and mobile telephony firms are, therefore, naturally interested in knowing the extent of the substitutability or complementarity between mobile telephone calls and SMSs. The critical regulatory question is whether there is a need for regulation of the wholesale market for SMS termination. For instance, on July 27 of 2006, the French sectorial regulator, ARCEP, became the first to impose the *ex-ante* regulation of the wholesale market for SMS termination. In the market analysis, ARCEP stated that voice and SMS are not substitutable because "SMS and voice correspond to different usages: voice is real time while SMS delivery is undetermined; SMS is more discrete; SMS is a social phenomenon using new forms of communication such as smileys: or teenager phonetic writing." The final conclusion was based on the fact that "the seasonal variations of traffic volumes are different for voice and data (SMS) on mobile networks", which, according to ARCEP, is evidence that SMS and calls are used for different purposes. This issue has been also debated by other national regulators. For instance, the Italian regulatory authority, AGCOM, for the purpose of a formal public consultation document delibera n. 465/04/CONS on Market 16: "voice call termination on individual mobile networks", commissioned a study, involving interviews with 2008 end-users. According to the outcome of the study, a significant majority of end-users consider SMS to represent an alternative for voice calls.[2]

This article sheds light into the question of whether mobile telephone calls and SMS are substitutes or complements. We estimate the price elasticities of demand for mobile telephone

[1] *Short Message Service* is a text message service that enables short messages, of generally no more than 160 characters in length, to be sent and received from a mobile telephone.

[2] See also the notes from the "Competitiveness Working Group Meeting: 14 August 2000" organized by Oftel for opinions of the representatives of the mobile telephony firms in the UK on the issue of substitutability or complementarity between telephone calls and SMSs, available at: *www.ofcom.org.uk/static/archive/oftel/ind−groups/mob − rev/cwg/2000/cwgm1.htm*. From these notes one can conclude that even mobile telephony firms have limited knowledge about the substitutability or complementarity between mobile telephone calls and SMSs, and about the price elasticity of demand for SMSs.

calls and messages. We use individual level data on the number of mobile telephone calls and messages, based on monthly invoices of a representative group of Portuguese consumers, between April 2003 and March 2004. The Portuguese mobile telephony industry consists of three firms: *Tmn*, *Vodafone*, and *Optimus*, with revenue market shares in 2005 of 50%, 37%, and 13%, respectively.

Figure 1 presents the monthly intensity of usage of mobile telephone calls and messages.

$[Figure\ 1]$

Consumers have heterogenous preferences for calls and messages. Some consumers send many messages and make few mobile telephone calls, and *vice-versa*. Clearly, the intensity of usage depends on some unobservable factors, which are unrelated to the price level. For instance, some consumers may make many mobile telephone calls or send many messages because of their life style. We account for data censoring, i.e., no mobile telephone calls or messages being made in certain months, and the unobservable individual heterogeneity in usage intensity, by estimating a Tobit model for panel data with individual random effects.

The demand for mobile telephone calls and the demand for messages are inelastic with respect to price. The price elasticity of demand for mobile telephone calls is -0.38, which agrees with the estimates from other countries. The price elasticity of demand for messages is -0.28. This is the first study that estimates the price elasticity of demand for messages using individual level panel data, so we cannot compare our result to others.

Interestingly, mobile telephone calls and messages are complements. The price elasticity of the demand for mobile telephone calls with respect to the price of messages is -0.06, and the price elasticity of the demand for messages with respect to the price of mobile telephone calls is -0.28.[3]

The demand for mobile telephone calls and the demand for messages are determined by observable consumer characteristics, such as the age and the gender. For instance, young consumers send by far more messages than older ones.

[3]It is possible that calls and messages are complements for some people and substitutes for other. This hypothesis could be tested using random price coefficients, from which we refrain in this study.

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.[4] To our knowledge, there is only one article that estimates the demand for SMS by Andersson et al. (2006). Using aggregate data from a Norwegian mobile telephony firm they find that the cross-price elasticity of the demand for voice depends on the size of the network. Voice is a substitute for SMS for small network sizes, and a complement for large network sizes. Our article contributes to the literature by estimating individual specific demands for the number of mobile telephone calls and messages. The panel structure of the data allows us to take into account the unobservable heterogeneity in the intensity of usage. There are very few studies that estimate the demand for mobile telephone calls with observable and unobservable individual effects. This is the first study of the dependence between the demand for mobile telephone calls and the demand for messages using individual level data.

The remainder of the paper is organized as follows. Section 2 presents the econometric framework. Section 3 describes the data and presents the estimation results. Section 4 concludes.

2 Econometric Model

In this section, we present the econometric model.

[4]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.

2.1 Demand Functions

We index consumers with subscript $i = 1, ..., N$, index firms with subscript $j = 1, ..., J$, and index time with subscript $t = 1, ..., T$. Denote by q^c_{ijt}, the numbers of the mobile telephone calls of individual i through firm j in period t, q^m_{ijt}, the numbers of the messages of individual i through firm j in period t, denote by p^c_{ijt}, the price of a call charged by firm j to individual i in period t, denote by p^m_{ijt} the price of a message charged by firm j to individual i in period t, and denote by X_i, a vector of characteristics of consumer i. The consumer characteristics are: **(i)** the age below 30 years, **(ii)** the age between 30 and 50 years, and **(iii)** the gender.[5]

After choosing a firm and a tariff, the consumer chooses the number of calls to make and the number of messages to send during the month.[6] We assume a linear demand function for the number of calls:

$$q^c_{ijt}(p^c_{ijt}, p^m_{ijt}) = \alpha^c p^c_{ijt} + \alpha^c_m p^m_{ijt} + X_i\beta^c + \delta^c_i + \epsilon^c_{ijt}. \tag{1}$$

where α^c is coefficient of the price of calls, α^c_m is the coefficient of the price of messages, β^c is a vector of parameters associated with the consumer characteristics, δ^c_i is an unobservable individual heterogeneity component, and ϵ^c_{ijt} is a stochastic error term. Let also $\gamma^c := (\alpha^c, \alpha^c_m, \beta^c)$, and $Z_{ijt} := \left(p^c_{ijt}, p^m_{ijt}, X_i\right)$. The unobservable individual heterogeneity component, δ^c_i, is uncorrelated across individuals, and follows the distribution $N(0, \sigma^2_{\delta^c})$. The stochastic error term, ϵ^c_{ijt}, is serially uncorrelated, and follows the distribution $N(0, \sigma^2_{\epsilon^c})$. In addition, the error term, ϵ^c_{ijt}, and the unobservable individual heterogeneity component, δ_i, are uncorrelated with the explanatory variables, Z_{ijt}.

The demand for messages is defined similarly, where $(\alpha^m, \alpha^m_c, \beta^m)$ are the parameters to be estimated.

[5]The data set includes two additional consumer characteristics: the residence in the Lisbon region, and the social class. However, they are insignificant in the model without random effects.

[6]Consumers of mobile services make interrelated decisions. First, they choose a firm. Second, they choose a tariff plan. Third, they choose the number of calls and the number of messages. Fourth, they choose the duration of the calls. We lack the information on the consumers' tariff plan choices. Thus, we cannot link the demands for calls and messages and the choice of a firm.

2.2 Log-Likelihood

The demands for calls and messages are censored at zero. Many consumers send no SMSs; others send messages but make no calls. Hence, the demand for calls may be defined as:

$$q^c_{ijt} = \begin{cases} \hat{q}^c_{ijt} & \hat{q}^c_{ijt} > 0 \\ 0 & \hat{q}^c_{ijt} \leq 0, \end{cases}$$

and similarly for messages. This specification requires estimating a Tobit model for panel data. For the observations for which $\hat{q}^c_{ijt}$ is positive, the contribution to the likelihood function is the probability density function, denoted by $\phi(\cdot)$. For the observations for which $\hat{q}^c_{ijt}$ is zero, the contribution to the likelihood function is the cumulative distribution function, denoted by $\Phi(\cdot)$. The conditional likelihood function for the observations of individual i is given by:

$$\mathcal{L}_i(q^c_{ijt}|Z_i, \delta^c_i) = \prod_{\hat{q}^c_{ijt}>0} \frac{1}{\sigma_\epsilon}\phi\bigg(\frac{q^c_{ijt} - (\delta^c_i + Z_{ijt}\gamma^c)}{\sigma_\epsilon}\bigg) \prod_{\hat{q}^c_{ijt}\leq 0} \Phi\bigg(\frac{-(\delta^c_i + Z_{ijt}\gamma^c)}{\sigma_\epsilon}\bigg).$$

Denote by $f(\cdot)$ the density of δ_i over the population. The unconditional likelihood is given by:

$$\mathcal{L}_i(q^c_{ijt}|Z_i) = \int \prod_{\hat{q}^c_{ijt}>0} \frac{1}{\sigma_\epsilon}\phi\bigg(\frac{q^c_{ijt} - (\delta^c_i + Z_{ijt}\gamma^c)}{\sigma_\epsilon}\bigg) \prod_{\hat{q}^c_{ijt}\leq 0} \Phi\bigg(\frac{-(\delta^c_i + Z_{ijt}\gamma^c)}{\sigma_\epsilon}\bigg) f(\delta^c_i) d\delta^c_i.$$

For the whole sample of individuals the log-likelihood may be written as:

$$\mathcal{L}(q^c_{ijt}|Z_{ijt}) = \sum_i \ln(\mathcal{L}_i(q^c_{ijt}|Z_{ijt})).$$

The log-likelihood function does not collapse into a sum, as it would in the case of a time series or a cross-section Tobit model. The likelihood function for individual i is an integral of a product, instead of just a product, and the log operator cannot be carried through the integral sign. All parameters are kept constant across firms. We estimate the demands for calls and messages separately.

The expected value of the endogenous variable in a Tobit model is given by:

$$\begin{aligned} E(q^c_{ijt}|Z_{ijt}, \delta^c_i) = E(q^c_{ijt}|Z_{ijt}, \delta^c_i, \widehat{q}^c_{ijt} > 0)\,\Pr(\widehat{q}^c_{ijt} > 0) + E(q^c_{ijt}|Z_{ijt}, \delta^c_i, \widehat{q}^c_{ijt} = 0)\,\Pr(\widehat{q}^c_{ijt} = 0) = \\ \left[\delta^c_i + Z_{ijt}\gamma^c + \sigma_\epsilon \frac{\phi\big(v^c_{ijt}\big)}{\Phi\big(v^c_{ijt}\big)}\right]\Phi\big(v^c_{ijt}\big) + 0\big(1 - \Phi\big(v^c_{ijt}\big)\big) = \\ (\delta^c_i + Z_{ijt}\gamma^c)\Phi\big(v^c_{ijt}\big) + \sigma_\epsilon\phi\big(v^c_{ijt}\big), \quad (2) \end{aligned}$$

where $v_{ijt}^c := \frac{\delta_i^c + Z_{ijt}\gamma^c}{\sigma_\epsilon}$. The marginal effect may be computed as (Greene, 1999):

$$\frac{\partial E(q_{ijt}^c | Z_{ijt}, \delta_i^c)}{\partial Z_{ijt}} = \gamma_i^c \Phi(v_{ijt}^c).$$

where γ_i^c is the coefficient associated with variable Z_{ijt}.

2.3 Consumer Surplus

The surplus from making calls of consumer i through firm j in period t is given by:

$$CS_{ijt}^c = \int_{\underline{p}_{ijt}^c}^{\hat{p}_{ijt}^c} q_{ijt}(p_{ijt}^c, p_{ijt}^m) dp_{ijt}^c,$$

where $\underline{p}_{ijt}^c$ is the price for a call in month t charged by firm j to individual i, and $\hat{p}_{ijt}^c(p_{ijt}^m)$ is the price for which $q_{ijt}^c = 0$, given p_{ijt}^m, i.e., the choke price. For the demand function (1), the consumer surplus for calls is:

$$CS_{ijt}^c = \int_{\underline{p}_{jt}^c}^{\hat{p}_i^c} \left(\alpha_m^c p_{jt}^m + \alpha^c p_{jt}^c + X_i\beta^c + \delta_i^c\right) dp_{jt}^c = (\alpha_m^c p_{jt}^m + \frac{\alpha^c}{2} p_{jt}^c + X_i\beta^c + \delta_i^c) p_{jt}^c.$$

The change in consumer surplus is, therefore:

$$\Delta CS_{ijt}^c = \left(\underline{p}_{jt}^c - \overline{p}_{jt}^c\right) \left[\alpha_m^c p_{jt}^m + \frac{\alpha^c}{2}\left(\underline{p}_{jt}^c + \overline{p}_{jt}^c\right) + X_i\beta^c + \delta_i^c\right]. \quad (3)$$

We get a similar expressions for the consumer surplus from sending messages.

The change in surplus cannot be calculated directly using the formula above, because of the unobservable individual heterogeneity component, δ_i^c. The change in the expected consumer surplus may be written as:

$$E(\Delta CS_{ijt}^c) = \left(\underline{p}_{jt}^c - \overline{p}_{jt}^c\right) \left[\alpha_m^c p_{jt}^m + \frac{\alpha^c}{2}\left(\underline{p}_{jt}^c + \overline{p}_{jt}^c\right) + E(q_{ijt}^c | X_{ijt}, \delta_i^c)\right], \quad (4)$$

where $E(q_{ijt}^c | Z_{ijt}, \delta_i^c)$ is computed using the expression (2) when both prices p_{jt}^c and p_{jt}^m zero.

3 Econometric Implementation

In this section, we describe the data, present the estimation results, and perform a consumer welfare exercise.

3.1 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.[7]

We count the number of calls and messages registered on monthly bills and their costs. Calls to mobile networks, calls to fixed networks, and messages account for 95% of the traffic, with calls representing 63% within this group.

The data set has two limitations. First, there is no information about the tariff plans chosen by the individuals. Second, there is little variation in prices within clients of each firm, and over time. We may conclude that most of the clients of each firm choose the same tariff plan, and do not change of tariff plan within our sample period.[8]

Since there is little price variation to identify the price coefficients, we estimate the demands for calls and messages jointly for all firms.

In Portugal, the mobile telephony firms require a minimum call duration of one minute, and consequently set a fixed charge for the first minute. We assume that consumers expect calls to last no longer than 60 seconds. In fact, based on the data from bills, about 57% of the calls are no longer than 60 seconds, and about 77% of the calls are no longer than 120 seconds. Thus, we define q^c_{ijt} to be the numbers of calls, and p^c_{ijt} to be the price of a one-minute call.

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

[7]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.

[8]For the subscribers of *Tmn* there more variation across tariff plans, than for the subscribers of *Optimus* and *Vodafone*, but no variation over time either. 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*.

invoices.[9] Unfortunately, we are unable to do this for many consumers.[10] Thus, we select only consumers for whom the prices of calls and messages in a given month do not vary with time and destination, or for whom the variation is negligible. The deletion of the consumers with more complicated tariff plans makes the sample unrepresentative. We lose the majority of subscribers of *Tmn* because of the complexity of its tariff plans.[11]

In certain months, some individuals made no calls. The panel nature of the data enables us to compare the prices paid the consumers over time. When we know the price consumers paid in the other months, we assume that in a given month, for which we lack data, consumers face the same prices.[12] Recall that few consumers change tariff plan over time.

[*Table* 1]

The total number of monthly invoices in our data set is 10, 588, as reported in the Table 1. In the estimation we use 5, 008 observations of monthly invoices, among which: 830 of *Tmn*, 16% of the invoices of this firm, 2, 465 of *Vodafone*, 79% of the invoices of this firm, and 1, 713 of *Optimus*, 88% of the invoices of this firm. These values imply market shares for *Tmn*, *Vodafone*, and *Optimus*, of 16.6%, 49.2%, and 34.2%, respectively.

3.2 Basic Estimation Results

We estimated two models.[13] In Model I, we estimate a Tobit model without individual random effects. In Model II, we estimate a Tobit model with individual random effects. Table

[9] 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.

[10] The tariff plans in mobile telephony are very complex and numerous. Prices may vary according to whether calls are: peak, off-peak, on-net, off-net, mobile-to-fixed, etc. Therefore, based only on the invoices it is difficult to determine which tariff plans individuals used.

[11] In the case of *Optimus* and *Vodafone*, the main tariff plans, do not seem to discriminate between calls to fixed networks and calls to mobile networks, as well as on-net and off-net calls, and peak and off-peak calls. In most tariff plans of *Tmn* such differentiation is present.

[12] For some individuals there is no reported traffic during a given month. We cannot determine whether these individuals generated no traffic, or generated traffic but did not provide their invoices.

[13] We use the Stata procedure xttobit to estimate the model. It uses the Gauss-Hermite quadrature and an adaptive quadrature to approximate the integral.

2 presents the estimation statistics, and Tables 3 and 4 present the estimates of Models I and II, respectively.

[*Table* 2]

[*Table* 4]

Model I has a substantially smaller likelihood value than Models II, which indicates the importance of individual random effects in the estimation of demand for calls and messages. Thus, we adopt Model II for the subsequent analysis.

Consumers aged below 30 years make less 4.3 calls than consumers aged above 30. Males make more 10 calls than females.

After controlling for unobservable consumer heterogeneity, the age of the consumers is the most important factor determining the demand for messages. Consumers aged below 30 send more 48.8 messages, than consumer older than 50 years. Consumers aged between 30 and 50 years send more 3.1 messages than older consumers. Males send less 2.8 messages than females. Besides, there is a significant unobservable consumer heterogeneity, captured by individual random effects in the panel data.

3.3 Price Elasticities

Table 5 presents the price elasticities of demand, and the marginal effects of the dummy variables of the demand functions.[14]

[*Table* 5]

The demand for calls and the demand for messages are inelastic with respect to price. The own-price elasticity of the demand for calls is -0.38. An increase in the average price of calls of 10% decreases the average number of calls by 3.8%. The own-price elasticity of the demand for messages is -0.28. An increase in the average price of messages of 10% decreases the average number of messages by 2.8%.

[14] The estimation of the price elasticities of demand and the marginal effects in a random effects Tobit is problematic because of the unobservable individual heterogeneity component. In practice, marginal effects are estimated using the mean value of δ_j^c.

Calls and messages are complements. In both equations, the estimates of the coefficients of the price of calls, and the price of messages have negative signs. But in the demand for messages the price of calls is significant only at a 10% level. This is probably due to the fact that there is little variation in prices across subscribers of a given firm. The cross-price elasticity of the demand for calls with respect to the price of messages is -0.06, and the cross-price elasticity of the demand for messages with respect to the price of calls is -0.28. A decrease in prices of calls has a stronger negative impact on the demand for messages, than the other way around. However, the symmetry of cross-price elasticities cannot be rejected at a 10% level.

4 Consumer Surplus

In the calculation of the consumer surplus we use the estimates from Table 4, for which the expected demands for zero prices of calls and messages take values: $E(q_{ijt}^c|Z_{ijt}, \delta_i^c) = 47.7$ and $E(q_{ijt}^m|Z_{ijt}, \delta_i^m) = 41.4$. Using formula (3), the expected loss in consumer surplus per month due to an increase in the price of one-minute calls by 10% is:

$$\Delta E(CS^c) = \underbrace{-0.1\underline{p}_{jt}^c \left[E(q_{ijt}^c|Z_{ijt}, \delta_i^c) + \alpha_m^c p_{ijt}^m + 2.1\frac{\alpha^c}{2}\underline{p}_{ijt}^c\right]}_{\text{calls}} - \underbrace{0.1\underline{p}_{jt}^c \left[E(q_{ijt}^m|Z_{ijt}, \delta_i^m) + 2.1\frac{\alpha_c^m}{2}\underline{p}_{ijt}^c + \alpha^m p_{ijt}^m\right]}_{\text{messages}}. \quad (5)$$

The first term on the right-hand side is the loss in surplus due to a decrease in the number of calls, while the second term is a loss in surplus due to a decrease in the number of messages. The expression for the expected loss in consumer surplus due to an increase in the price of messages, $\Delta E(\Delta CS^m)$, is defined similarly.

In order to get some sense of the magnitude of these effects, we assume that the prices for messages and one-minute calls in euros are the average observed prices, i.e.: $p_{ijt}^m = 0.087$ euro and $p_{ijt}^c = 0.22$ euro, for all consumers and firms. Thus, the expected loss in consumer surplus due to an increase in the price of calls by 10% is: $E(\Delta CS^c) = -0.685 - 0.267 = -0.951$ euro.[15]

[15]This calculation does not include the loss in consumer surplus due to a decrease in the duration of calls. However, Grzybowski and Pereira (2007) estimate the price elasticity for the demand for the duration of calls to

An increase in the price of messages by 10% leads to a loss in consumer surplus of 0.381, which can be decomposed in 0.105 due to the decrease in the number of messages, and 0.276 due to the decrease in the number of calls.[16]

These numbers have a clear, although unsurprising, implication. If one measures the impact of an increase in the price of one of these services without taking into account the demand for the other service, one underestimates the true magnitude of the impact. In the case of the increase in the price of messages the result could be very misleading, since the direct effect, 0.105, represents only 27.6% of the total effect, 0.381.

5 Conclusions

This article uses Portuguese consumer level data to estimate the price elasticities of demand for calls and messages. We account for data censoring, that is zero number of calls and messages in certain months, and the unobservable heterogeneity in usage intensity by estimating a Tobit model for panel data with individual random effects. We find that the demand for calls and the demand for messages are inelastic with respect to price. In addition, calls and messages are complements. Demands for calls and messages are determined by observable consumer characteristics, such as the age and the gender.

be very inelastic, in the order of -0.2.

[16]The average monthly bill value computed for the sample of consumers between April 2003 and March 2004 amounted for 15.92 euros.

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Appendix

Table 1: 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 2: Random Effects Tobit Regressions for Duration, Number of Calls and Messages

	Calls	SMS	Calls	SMS
Number of obs	5008	5008	5008	5008
Censored	79	1989	79	1989
Number of groups			678	678
Obs per group: min			1	1
avg			7.4	7.4
max			24	24
Wald χ^2			124.39	1130.4
Prob> χ^2			0.0000	0.0000
Log likelihood	-24044	-18064	-22042	-16466

Table 3: Tobit Regression without Random Effects: Demand for Calls and Messages – Model I

SMS						
Parameter	Estimate	z	$Pr > \|z\|$	Lower	Upper	
const	46.449	3.25	0.001	18.41	74.48	
price calls	-132.475	-3.52	0.000	-206.29	-58.65	
price SMS	-668.834	-4.82	0.000	-940.74	-396.92	
age< 30	93.298	31.40	0.000	87.47	99.12	
age< 50	29.579	11.20	0.000	24.40	34.75	
male	-5.350	-2.54	0.011	-9.47	-1.22	
Calls						
Parameter	Estimate	z	$Pr > \|z\|$	Lower	Upper	
const	48.212	12.56	0.000	40.68	55.73	
price calls	-61.757	-3.79	0.000	-93.74	-29.77	
price SMS	-23.013	-2.38	0.017	-41.97	-4.05	
age< 30	-6.984	-5.68	0.000	-9.39	-4.57	
age< 50	0.097	0.09	0.925	-1.93	2.13	
male	0.746	0.84	0.403	-1.00	2.49	

Table 4: Tobit Regression for Panel Data with Random Effects: Demand for Calls and Messages – Model II

SMS						
Parameter	Estimate	z	$Pr > \|z\|$	Lower	Upper	
const	-7.971	-0.87	0.384	-25.92	9.97	
price calls	-61.333	-1.77	0.077	-129.34	6.68	
price SMS	-171.535	-2.56	0.011	-302.96	-40.11	
age< 30	90.338	29.63	0.000	84.36	96.31	
age< 50	9.020	3.85	0.000	4.42	13.61	
male	-9.254	-4.53	0.000	-13.25	-5.25	
σ_δ	69.597	53.70	0.000	67.05	72.13	
σ_ϵ	37.441	75.39	0.000	36.46	38.41	
ρ	0.775			0.75	0.79	
Calls						
Parameter	Estimate	z	$Pr > \|z\|$	Lower	Upper	
const	42.868	14.06	0.000	36.89	48.84	
price calls	-61.966	-4.76	0.000	-87.45	-36.47	
price SMS	-26.012	-4.21	0.000	-38.12	-13.89	
age< 30	-5.680	-2.90	0.004	-9.52	-1.83	
age< 50	-1.977	-1.26	0.207	-5.04	1.09	
male	12.107	8.65	0.000	9.36	14.85	
σ_δ	27.902	70.66	0.000	27.12	28.67	
σ_ϵ	17.791	94.31	0.000	17.42	18.16	
ρ	0.710			0.69	0.72	

Table 5: Elasticities and Marginal Effects

Calls						
variable	dy/dx	z	$P > \|z\|$	Lower	Upper	
price calls	-0.384	-4.63	0.000	-0.547	-0.221	
price SMS	-0.056	-4.24	0.000	-0.082	-0.030	
age< 30	-4.301	-2.90	0.004	-7.213	-1.390	
age< 50	-1.532	-1.25	0.210	-3.926	0.861	
male	10.073	7.88	0.000	7.567	12.580	
SMS						
price calls	-0.284	-1.75	0.080	-0.601	0.033	
price SMS	-0.277	-2.55	0.011	-0.490	-0.063	
age< 30	48.779	25.49	0.000	45.028	52.530	
age< 50	3.080	3.91	0.000	1.537	4.623	
male	-2.777	-4.55	0.000	-3.973	-1.581	

Figure 1: Number of Calls to Mobiles and Number of Messages per Month between April 2003 - March 2004