Delineating Markets for Bundles with Consumer Level Data: The Case of Triple-Play*

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Abstract

The question of whether bundles of telecommunication services are relevant product markets is addressed. As a first step, demand for bundles of services, as well as the associated services, is modeled as a discrete choice problem with a potentially large number of products. A unique invoice based consumer level data set from Portuguese telecommunications firms is collected. This choice based data set is combined with survey data to characterize the market shares of all potential combinations of services available. Several discrete choice models are estimated. A Cross-Nested logit model is the most parsimonious description of the substitution patterns between the large number of products available. The demand model used, coupled with the definition of choice alternatives proposed, generates flexible substitution patterns, which produce reasonable price elasticities of demand. The demand for triple-play products is elastic, with own-price elasticities for the larger firms ranging between 3.2 and 1.3, and a market own-price elasticity of 1.4. Some of the products analyzed are found to be complementary. Our results indicate that triple-play bundles are a relevant product market.

Key Words: *Bundles, Relevant Market, Triple-play, Consumer level data.*

JEL Classification: D43, K21, L44, L96.

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1 Introduction

Triple-play bundles, i.e., bundles of fixed telephony, fixed broadband access to the internet and subscription television, are becoming very important for the telecommunications industry. An increasing number of households seem to prefer to consume these bundles, instead of consuming their components separately. In addition, telecommunications firms seem to increasingly base their marketing strategies on these products. The growing importance of triple-play products poses several problems for competition authorities and sectoral regulators discussed in Pereira and Vareda (2011).

The definition of the relevant market and the analysis of market power are fundamental components of competition and regulatory policy. To determine whether a firm's conduct is anticompetitive, it is necessary to establish first that the firm has significant marker power, which in legal terms means establishing that the firm is dominant. In turn, the notion of market power, or dominance, is defined in reference to a particular relevant market.[1]

The current practice in the telecommunications industry, both for competition and regulatory proceedings, is to consider only relevant markets for individual services. However, as the importance of bundles of telecommunication services grows, the question of whether these new products constitute separate relevant markets naturally arises. This issue is important because dominance on individual services does not imply dominance on bundles, and vice-versa. For example, a firm may be dominant in the markets of fixed telephony products and fixed broadband products, while another firm may be dominant in the market for triple-play products. Hence, depending on which market the competition analysis is framed, the conduct of a given firm may be found to be anticompetitive or not. Similarly in merger review cases, depending on which relevant product markets are considered, a given merger may be found to substantially lessen competition or not. In regulatory proceedings usually only wholesale markets are regulated. However, the evaluation of whether a wholesale market is competitive is made with reference to the associated retail market. If it is established at the retail level that bundles constitute a relevant product market, then it may be appropriate to define a relevant product market for bundles at the wholesale level, which in turn requires the re-examination of which markets are susceptible of ex ante regulation, or finding other regulatory mechanisms.

In this article, we perform the small but significant and non-transitory increase in price (SSNIP) test to determine if triple-play products are a relevant market, in the sense of competition policy. As a first step, we model and estimate the demand for bundles of services, as well as the associated services, as a discrete choice problem with a potentially large number

[1] For abuse of dominance cases in the EU, or monopolization cases in the US, market definition helps to determine whether a firm has enough market power to engage in anticompetitive behavior. For merger cases, market definition helps to identify the firms that could constrain possible price increases by merging parties. For regulation cases, the evaluation of whether a wholesale market is competitive is made with reference to the associated retail market.

of products. The demand estimates are used to perform the SSNIP test, which shows that triple-play bundles are a relevant product market. This may change considerably the competition analysis related to these products. More broadly, we show that a set of products consisting only of bundles may constitute a relevant product market. The demand estimates also allow us to compute price elasticities of demand for bundles of telecommunications services, namely triple-play products, which is of independent interest. We choose triple-play bundles for illustrative purposes and because of their growing importance. Both the underlying questions and the methodologies developed apply more broadly to any bundle of services, namely to double-play or quadruple-play bundles.

To conduct a SSNIP test one has to determine the substitutability between the product candidates to the relevant market, measured by the price elasticities of demand. In the case of bundles, this exercise may be complex because it involves determining the substitutability between products of the same type and also the substitutability between products of different types. For triple-play products, one needs to determine not only the substitutability between different triple-play bundles, but also the substitutability between triple-play and double-play bundles, and the substitutability between triple-play bundles and individual products. Hence, the first and most important challenge one faces when delineating markets for bundles is how to estimate coherently the demand for the various types of bundles and individual services. This problem can be overcome with a careful definition of the consumers' choice alternatives. Once this is done, the consumers' choice problem can be cast within the discrete choice framework and the demand for bundles and individual products can be estimated using standard techniques.

A ***choice alternative*** is defined as a combination of: **(i)** the three triple-play services, whether in a bundle or not, **(ii)** the type of bundle, and **(iii)** the supplier of each of the services. This definition is important for two reasons. First, it allows framing bundle choices in standard discrete choice models. Second, it allows using existing survey data to estimate the aggregate share of each product.

We created a unique invoice based consumer level data set with information collected from six Portuguese telecommunications firms, which account for 99% of triple-play customers. Our data set consists of a cross-section with 3.243 observations for December 2009. This choice based data set was calibrated using publicly available survey data.

Our data set only includes the households' choices, not their choice sets. Besides, there is a very large number of alternatives. To deal with both of these problems we follow the approach of Train, McFadden, and Ben-Akiva (1987). For each choice in the sample, we impute nine other alternatives available in the household's area of residence. This imputation process creates potentially an endogeneity problem. We account for both the usual endogeneity problem associated with non-observable characteristics of differentiated products, and the endogeneity problem created by the imputation process, by using the control function approach in the estimation process. For an application of the control function approach in the context of discrete choice models see, e.g., Petrin and Train (2010).

We estimate four discrete choice models, namely a Multinomial Logit, a Nested Logit, a Cross-Nested Logit and a Mixed Logit model. A Cross-Nested Logit demand model, with a nest for the type of bundle and a nest for firms, provides the most parsimonious description of the substitution patterns between the large number of products available.

The Cross-Nested Logit model, see e.g., Bierlaire (2006), inherits the theoretical foundations of random utility theory from the Generalized Extreme Value class, and has the Multinomial Logit and the Nested Logit models as special cases. This parsimonious specification captures different substitution patterns between different types of bundles and between the products of different firms, while maintaining a closed form probability formula. In particular, it allows modeling the clustering of products along several dimensions, which may form non-mutually exclusive groups. This flexibility is important for our purposes, since the reliability of our simulation results derives from the ability to estimate demand as realistically as possible, within the limitations of the data. Previous applications of the Cross-Nested Logit model in economics include Adams, Brevoort, and Kiser (2007), Bresnahan, Stern, and Trajtenberg (1997) and Small (1987).

The demand model used, coupled with the definition of choice alternatives proposed, generates flexible substitution patterns, which produce reasonable price elasticities of demand. The estimates show that the demand for triple-play products is elastic, with own-price elasticities ranging between 3.2 and 1.3 for the largest firms, and a market own-price elasticity of 1.4. Some of the products analyzed are found to be complementary. For example, the double-play product of fixed voice and fixed broadband is a complement of the single-play product of subscription television.

We perform three versions of the SSNIP test. The first version, the ***unilateral price increase***, involves calculating the change in profits caused by a 5% or 10% price increase in different subsets of products controlled by a hypothetical monopolist. This version is based on the 1997 notice of the European Commission (EC) on the definition of the relevant market. The second version, the ***equilibrium price increase***, involves simulating the equilibrium prices that would occur if a hypothetical monopolist controlled different subsets of products. This version is based on the US Department of Justice and Federal Trade Commission 1984 Merger Guidelines. Finally, the third version, the ***upward pricing pressure***, is based on the recently introduced homonymous test of Farrell and Shapiro (2010).

The three versions of the SSNIP test indicate that triple-play products are a relevant product market in Portugal. This result illustrates the possibility that a set of products consisting only of bundles may constitute a relevant product market.

Our analysis relates to two literature strands.[2] First, our article relates to the literature

[2]More generally, our methodological approach draws on the discrete choice literature, represented by, e.g., Domencich and McFadden (1975), McFadden (1974), McFadden (1978), and McFadden (1981), or in

that models and estimates the choice over bundles, which includes: Augereau, Greenstein, and Rysman (2006), Gandal, Markovich, and Riordan (2004) and Gentzkow (2007).[3] These articles developed alternative approaches to model the demand for bundles of two goods. Second, our article also relates to the empirical literature on market delineation, which includes: Adams, Brevoort, and Kiser (2007), Brenkers and Verboven (2006), Capps, Dranove, and Satterthwaite (2003), Davis (2006), Ivaldi and Lörincz (2009), Ivaldi and Verboven (2005) and Filistrucchi, Klein, and Michielsen (forthcoming). These articles used data from various industries to perform some of the versions of the SSNIP test.

Our article has three contributions. First it shows how demand for bundles of services, as well as the associated services, can be modeled as a discrete choice problem with a potentially large number of products. Note that the existing examples in the literature of demand systems for bundles involve a small number of products. The second contribution is to compute for the first time price elasticities of demand for bundles of telecommunications services, namely triple-play products. The third contribution is to show, for the particular case of triple-play, that a set of products consisting only of bundles may constitute a relevant product market, which may change considerably the competition analysis of the underlying markets.

The rest of the article is organized as follows. Section 2 gives an overview of the Portuguese industry. Section 3 describes the three SSNIP tests performed. Section 4 presents the demand model. Section 5 describes the data, the econometric implementation and the basic estimation results. Section 6 performs the SSNIP test for the relevant product market. Section 7 discusses the robustness of the results and Section 8 concludes.

2 The Portuguese Industry

Portugal Telecom (PT), the telecommunications incumbent, was privatized in 1996.

The industry was liberalized in 2000. Initially, entrants based their offers of fixed voice and broadband access services in the wholesale access to PT's cooper wire network. Later, as they obtained a substantial customer base, entrants resorted to the unbundled access to PT's local loop. After 2006 there was a large increase in the number of unbundled loops. As a consequence, many innovative products, for instance bundles, were introduced in the market. In the meanwhile, some entrants invested in their own infrastructures, increasing further their autonomy. In November 2007, ZON, a cable television firm, was spined-off from PT. This was an important change in the Portuguese industry. ZON, using its cable

the industrial organization side by, e.g., Berry (1994), Berry, Levinsohn, and Pakes (1995), Goldberg (1995) and Nevo (2001).

[3] Liu, Chintagunta, and Zhu (2010) using the model of Gentzkow (2007) find strong complementarities between subscription television and fixed broadband/cable modem and between fixed voice and fixed broadband/DSL.

television network, started to compete with PT, using its telephone network.[4] Recently, PT initiated the deployment of a fiber-optic network, while ZON upgraded its cable network by installing DOCSIS 3.0.

The other relevant firms in the industry include AR Telecom, Cabovisão, Optimus and Vodafone. AR Telecom began operations in 2005, basing its products mainly on fixed wireless access technology. Cabovisão, a cable television firm, was created in 1995. Optimus, originally a mobile telecommunications firm, entered the fixed services business in 2000 using local loop unbundling, with access via Digital Subscriber Line (DSL). After 2008 it also started deploying its fiber-optic network. Vodafone, originally a mobile telecommunications firm, entered the fixed services business in 2000, using local loop unbundling, with access by DSL.

In 2009, the penetration rate per inhabitant of fixed telephony was 40%. After a long period of decline, the penetration rate of fixed telephony started to increase again. Also in 2009, the penetration rate per household of subscription television was 45%. Of these subscribers 57.4% used cable and 23.2% Direct to Home (DTH) technology.[5] Finally, in 2009 the penetration rate per inhabitant of fixed broadband was 18%. Of these subscribers 57% access through DSL and 40% through cable modem.

Table 1 presents the markets shares of the largest telecommunications firms in 2008 and 2009 for each type of service.

[*Table* 1]

Telecommunications bundles were first offered in Portugal in 2004 through cable television networks. Afterwards, several firms launched similar products using fixed telephony networks, either through local loop unbundling or their own networks.

Table 2 presents average monthly prices in 2009 for various products of the final dataset used in the estimation. The construction of this dataset is detailed in Section 5.2.[6]

[*Table* 2]

Bundles of triple-play and double-play of fixed telephony and fixed broadband are sold at a discount relative to the individual components. For the population that buys the three services, whether in a bundle or not, triple-play bundles, on average, cost 55.9€ per month, whereas buying the three components separately costs 76€, which represents a discount of 26, 4%. For the population that does not buy subscription television, double-play bundles of fixed telephony and fixed broadband, on average, cost 23.4€ per month, whereas buying

[4] For more details see Pereira and Ribeiro (2011).

[5] In Portugal there are no independent satellite television firms. Two of the telecommunications or television firms offer satellite television services as complements to their other services in the regions not covered by their physical networks.

[6] Note that the construction of this dataset requires imputing some variables.

the two components separately costs 34, 8€, which represents a discount of 33%. Regarding the double-play bundles of fixed telephony and subscription television and of subscription television and fixed broadband there is no significant difference between the price of the bundle and the sum of the prices of the individual components.

3 Relevant Market and SSNIP Test

The ***relevant market***, in the sense of competition policy, is the smallest set of products and locations with respect to which a hypothetical monopolist has substantial market power.

Both economic analysis and case law indicate the SSNIP test as the correct method of delineating the relevant market. See Werden (1983) and Werden (1993). Next we describe briefly the three versions of the SSNIP test performed. See Appendix A for details.

The first version, to which we refer as the ***unilateral price increase*** (UPI), is based on the 1997 notice of the EU Commission: "Commission Notice on the Definition of the Relevant Market for the Purposes of Community Competition Law" (Official Journal of the European Communities, C/372, 9.12, pg. 5.). This version lays the weight of market delineation on the possibility of a hypothetical monopolist raising ***unilaterally*** the price of the products it controls by 5% or 10%. Consider a set of products. Suppose that initially each product is controlled by a different firm, and that the observed prices are equilibrium prices. Now suppose that a firm called the hypothetical monopolist controls two products. Let the hypothetical monopolist raise its prices by 5% or 10%. If the hypothetical monopolist's profit increases, those two products constitute a relevant product market; otherwise the exercise should be repeated with the hypothetical monopolist controlling an additional product. The ***relevant product market*** is the smallest set of products whose price could be increased profitably by a hypothetical monopolist.

The second version, to which we refer as the ***equilibrium price increase*** (EPI), is based on the 1984 U.S. Department of Justice and Federal Trade Commission Merger Guidelines.[7] This version lays the weight of market delineation on the possibility of, in ***equilibrium***, a hypothetical monopolist increasing the prices of the products it controls.[8] Again consider a set of products. Suppose that initially each product is controlled by a different firm, and that the observed prices are equilibrium prices. Suppose now that the hypothetical monopolist controls two products. Compute the equilibrium prices associated with this new property structure. If the average of the hypothetical monopolist's prices at the new equilibrium is higher than the average of those prices at the initial equilibrium by at least 5% or 10%, those two products constitute a relevant product market; otherwise the exercise should be repeated with the hypothetical monopolist controlling an additional product. The ***relevant***

[7] See http://www.justice.gov/atr/hmerger/11249.pdf.

[8] Ivaldi and Lörincz (2009) discuss at length the relative merits of the first and second versions of the SSNIP test.

product market is the smallest set of products whose prices, in equilibrium are, on average, at least 5% or 10% higher, if controlled by a hypothetical monopolist, than if controlled by separate firms.

Finally, the third version, to which we refer as the ***upward pricing pressure*** (UPP) is based on the recently introduced homonymous test of Farrell and Shapiro (2010). This version can be interpreted as an intermediate step to calculating the full equilibrium of the EPI. Consider again a set of products. Suppose that initially each product is controlled by a different firm, and that the observed prices are equilibrium prices. Suppose now that the hypothetical monopolist controls two products. However, each product belongs to a separate division of the hypothetical monopolist. Each division chooses its prices to maximize only its divisional profit, therefore ignoring the impact of its decision on the other division's profit. The management of the hypothetical monopolist wants to set prices that maximize joint profits in a decentralized manner. One first step to achieve this would be to impose on the two divisions unit taxes that internalize the cannibalization of the other division's profits. These taxes can be interpreted as the upward pricing pressure on prices induced by the joint optimization of profits by the hypothetical monopolist. The values of the taxes are an approximation of the average equilibrium variation of the hypothetical monopolist's prices.

When sales occur at the producers' locations, location can be treated as just another product attribute. Hence, the product and the geographic markets can be delineated in a unified way. When sales occur at the consumers' location, which is our case, then the delineation of the product and geographic markets require different treatments. We will first focus on the delineation of the product market, under the assumption that competition conditions regarding triple-play products are homogeneous within the country, i.e., the geographic market is the whole country.[9] Later, in Section 7.2, we will investigate whether competition conditions regarding triple-play products vary across regions within the country.

4 Demand Model

4.1 Utility Function

We propose the class of Generalized Extreme Value (GEV) models to characterize demand.[10] GEV models characterize the demand of individuals for products of a discrete nature, and consequently, are particularly suited to the type of products under analysis, as well to the type of data collected. The Multinomial Logit (MNL), the Nested Logit (NL) and the Cross-Nested Logit (CNL) are elements of this class. Moreover, the CNL model is flexible enough to approximate any consumer choices consistent with the assumption of

[9]Portugal has a population of $10,5$ million and an area of 92.000 square kilometers.

[10]See McFadden (1978).

random utility maximization.[11]

Household $h = 1, ..., H$ derives from choice alternative $s = 1, ..., S$ utility:

$$U_{hs}(p_{hs}, \mathbf{x}_{hs}, \boldsymbol{\theta}) = V_{hs}(p_{hs}, \mathbf{x}_{hs}, \boldsymbol{\theta}) + \varepsilon_{hs}, \tag{1}$$

where p_{hs} is the price of alternative s for household h, $\mathbf{x}_{hs}$ is a $T \times 1$ vector of characteristics of alternative s for household h other than price, $\boldsymbol{\theta}$ is the vector of parameters to be estimated, and ε_{hs} is a non-observed utility component of alternative s for household h. We assume additionally that:

$$V_{hs}(p_{hs}, \mathbf{x}_{hs}, \boldsymbol{\theta}) := p_{hs}\alpha + \sum_{t=1}^{T} x_{hsj}\beta_t, \tag{2}$$

where α is the price coefficient and parameters β_t translate the consumer's valuation for characteristics $t = 1..., T$, other than price, of the various alternatives. Let $\boldsymbol{\beta} := (\beta_1, ..., \beta_T)$ and $\boldsymbol{\theta} := (\alpha, \boldsymbol{\beta})$. Whenever possible, index h will be omitted.

4.2 Choice Probabilities

A consumer chooses alternative s which generates the maximum utility level U_s, i.e., $U_s > U_j$, for all $j \neq s$. The probability of a consumer choosing alternative s depends on the joint distribution of components ε_s. Different joint distributions of ε_s lead to different demand models. Let $z_s := \exp(V_s)$. The GEV class of demand models can be characterized by probability generating functions $G(z_1, \ldots, z_S)$, and the probability of alternative s from set $\mathcal{C}$ being chosen is given by:

$$P(s|\mathcal{C}) = \frac{z_s G_s(z_1, \ldots, z_S)}{G(z_1, \ldots, z_S)};$$

where $G_s := \frac{\partial G}{\partial z_s}$, and S is the number of alternatives of set $\mathcal{C}$. Functions $G(\cdot)$ must obey certain properties, namely homogeneity of degree 1.[12] Hence, the expression above can be written as:

$$P(s|\mathcal{C}) = \frac{z_s G_s(z_1, \ldots, z_S)}{\sum_t z_t G_t(z_1, \ldots, z_S)};$$

or:

$$P(s|\mathcal{C}) = \frac{\exp(V_s + \ln G_s)}{\sum_t \exp(V_t + \ln G_t)}.$$

Different choices of $G(\cdot)$ lead to different demand models.

Let subsets $\mathcal{B}_w$, with $w = 1, \ldots, W$, be subsets of $\mathcal{C}$ not necessarily mutually exclusive. The CNL model follows from:

$$G(z_1, \ldots, z_S) = \sum_{w=1}^{W} \left(\sum_{s \in \mathcal{B}_w} \delta_{ms} z_s^{1/\lambda_w} \right)^{\lambda_w}. \tag{3}$$

[11] For a discussion of the properties of the CNL model see, e.g., Bierlaire (2006), Fosgerau, McFadden, and Bierlaire (2010), Wen and Koppelman (2001), and Koppelman and Sethi (2007).

[12] See, e.g., McFadden (1978), for the complete characterization of function $G(\cdot)$.

Let constants δ be normalized to 1.

The expression for $G(\cdot)$ for the MNL and NL models can be obtained as particular cases of (3).[13]

Applying the definition of $P(s|\mathcal{C})$ with function $G(\cdot)$ defined for the CNL, and making use of the normalization, one obtains:

$$P(s|\mathcal{C}) = \sum_{w=1}^{W} \mathbf{1}_{s\in\mathcal{B}_w} \frac{\exp(V_s/\lambda_w)}{\sum_{k\in\mathcal{B}_w}\exp(V_k/\lambda_w)} \frac{\left[\sum_{k\in\mathcal{B}_w}\exp(V_k/\lambda_w)\right]^{\lambda_w}}{\sum_{m=1}^{W}\left[\sum_{k\in\mathcal{B}_m}\exp(V_k/\lambda_m)\right]^{\lambda_m}}.$$

Let:

$$P(s|\mathcal{B}_w) := \mathbf{1}_{s\in\mathcal{B}_w} \frac{\exp(V_s/\lambda_w)}{\sum_{k\in\mathcal{B}_w}\exp(V_k/\lambda_w)},$$

and

$$P(\mathcal{B}_w|\mathcal{C}) := \frac{\left[\sum_{k\in\mathcal{B}_w}\exp(V_k/\lambda_w)\right]^{\lambda_w}}{\sum_{m=1}^{W}\left[\sum_{k\in\mathcal{B}_m}\exp(V_k/\lambda_m)\right]^{\lambda_m}}.$$

Then, one has the simple interpretation of:

$$P(s|\mathcal{C}) = \sum_{w=1}^{W} P(s|\mathcal{B}_w)P(\mathcal{B}_w|\mathcal{C}).$$

4.3 Price-Elasticities of Demand

For the case of the CNL model, the elasticity of product i with respect to the price of product j is:

$$\varepsilon_{ij} = \begin{cases} \alpha p_i \left[1 - P(i|\mathcal{C}) + \sum_{w=1}^{W}\phi_{iw}\frac{1-\lambda_w}{\lambda_w}\left(1 - P(i|\mathcal{B}_w)\right)\right] & j = i \\ -\alpha p_j \left[P(j|\mathcal{C}) + \sum_{w=1}^{W}\phi_{iw}\frac{1-\lambda_w}{\lambda_w}P(j|\mathcal{B}_w)\right] & j \neq i, \end{cases} \tag{4}$$

with

$$\phi_{iw} := \frac{P(i|\mathcal{B}_w)P(\mathcal{B}_w|\mathcal{C})}{P(i|\mathcal{C})}.$$

Note that by definition: $\sum_{w=1}^{W}\phi_{iw} = 1$.

The expressions for ε_{ij} for the MNL and NL models are obtained as particular cases of (4).[14]

[13] The MNL model follows from: $G(z_1,\ldots,z_S) = \sum_{s=1}^{S} z_s$. Let $\mathcal{B}_w$ be mutually exclusive subsets which form a partition of $\mathcal{C}$. The NL model follows from: $G(z_1,\ldots,z_S) = \sum_{w=1}^{W}\left(\sum_{s\in\mathcal{B}_w} z_s^{1/\lambda_w}\right)^{\lambda_w}$.

[14] For the NL model, $\phi_{iw} = 0$ if i does not belong to $\mathcal{B}_w$. Since sets $\mathcal{B}_w$ are mutually exclusive, $\sum_{w=1}^{W}\phi_{iw}$ only has one strictly positive element. For the MNL model, we have in addition that $\lambda_w = 1$ and $\mathcal{B}_w = \mathcal{C}$.

5 Econometric Implementation

5.1 Data

5.1.1 Data Request

We obtained data from the last quarter of 2009 from six Portuguese electronic communication firms, which accounted in December 2009 for 99% of triple-play customers. For confidentiality reasons, we will refer to these firms as $f_1, ..., f_6$.

The information obtained consisted of data about: **(i)** the contract, **(ii)** the product, **(iii)** the client, and **(iv)** monthly expenditures. The characteristics of the contract are: the monthly fee, discounts or joining offers, the commencement date of the contract, and the characteristics of the product. The characteristics of the product are: the brand name, the number of normal and premium television channels and the possibility of access to video-on-demand, if the product included subscription television, bandwidth, traffic limits, number of e-mail accounts and the possibility of mobile broadband, if the product included fixed broadband access to the Internet, and the tariff plan for fixed telephony. The characteristics of the client are: age, length of the contract and residential postal code.

We also obtained billing information for the last quarter of 2009, with full detail of invoices, including the fixed monthly fee and variable components, e.g., movie rentals, channel rentals, internet traffic above contracted limits, expenditure on telephone calls and minutes of conversation.

Finally, we obtained the total number of clients for each product offered, and the geographical availability of each product.

This data was complemented with information from the sectoral regulator, ICP-ANACOM, drawn from the survey "Inquérito ao consumo dos serviços de comunicações electrónicas - População residencial – Dezembro de 2009", from, hereon "Inquérito ao consumo", which characterizes the typical national consumer of electronic communication services.

5.1.2 Choice Alternatives

A ***choice alternative*** is a combination of: the three services, the type of bundle or form of acquisition, and the supplier of each of the three services.

Table 3 details the possible combinations of: services, forms of acquisition and firms.

[*Table* 3]

There are eight possible combinations of services, six possible types of bundles, and seven possible suppliers, with one, f_0, corresponding to the inexistence of a supplier. There are 475 possible combinations of: services, bundles and supplier of each service.[15] Since some firms do not supply certain combinations of services and bundles, the number of combinations effectively available is 76. Each one of these combinations is treated as a distinct choice alternative, i.e., $S = 76$.

Table 4 illustrates some choice alternatives.

[$Table$ 4]

The concept of choice alternative does not coincide with the concept of a product offered by a firm. A product offered by a firm may be present in several choice alternatives. For example, fixed telephony offered by a given firm is typically present is several choice alternatives. In fact, a product offered by a firm is present only in one choice alternative in the case of triple-play bundles. With this definition of the choice alternative, the consumer's choice problem can be cast within the discrete choice framework, and standard techniques can be applied to estimate the demand for bundles and individual products coherently.

5.1.3 Market Distribution of Services

The information from *Inquérito ao consumo* allowed us to relate the electronic communication services consumed by households to the way they are acquired, and to obtain the percentage of households that do not consume any of these services. Next we report this information in intervals for confidentiality reasons.

Table 5 presents the distribution of services by type of bundle in 2009.

[$Table$ 5]

This information, and the data obtained from the firms, allowed us to determine the distributions of the services per household and the market shares per firm for each service, shown in Table 6, and for each type of bundle, shown in Table 7.

[$Table$ 6]

[$Table$ 7]

The choice alternatives defined in Section 5.1.2 are the combination of five discrete variables. The share of each choice alternative is given by the joint distribution of these variables. Tables 5, 6 and 7 have the marginal distributions of the five variables that define the choice alternatives. The joint distribution of the five variables that define a choice

[15] Of the total of combinations services$\times$bundles$\times$FV supplier$\times$TV supplier$\times$BB supplier$= 8 \times 6 \times 7 \times 7 \times 7 = 16464$ we eliminated the combinations: **(i)** without supplier and with product; **(ii)** with supplier and without product; **(iii)** double-play with different suppliers for the double-play services, and **(iv)** triple-play with different suppliers for the triple-play services.

alternative is computed from the partial information contained in Tables 5, 6 and 7 through a maximum likelihood procedure. This estimation approach is standard in the analysis of multivariate discrete distributions with partial data, and the computation can be made, e.g., using the Iterative Proportional Fitting algorithm.[16]

5.2 Choice Sets and Identification

Our data, described in Section 5.1.1, is by construction a choice based sample, i.e., a sample stratified on the choice each consumer made. Hence, it does not reflect overall market shares, and induces sample selection bias if not corrected. There are several alternative techniques to correct this bias. See, e.g., Manski and McFadden (1981), in particular chapters 1 and 2. The first method that appeared in the econometrics literature addressing this issue was the Weighted Exogenous Sampling Maximum Likelihood (WESML) estimator of Manski and Lerman (1977).

The WESML requires extra data on overall population product shares. These shares are used to construct weights for each observation. The WESML is simply a standard maximum likelihood procedure where the observations are weighted using these specified weights. Any weighted estimation procedure can also be implemented by resampling the data using the weights and then applying the estimation procedure to the resampled data without weights.

In this article we used the data obtained from the firms, described in Section 5.1.1, and the weights described and computed in Section 5.1.3, to build a sample representative of the weight of each choice in the population. An observation of this sample represents a consumer's choice and is obtained by re-sampling the original data. This resampled data was then used in the estimation, i.e., we followed the resampling version of the WESML procedure.

We do not observe the consumers' choice sets, just the consumers' choices. In addition, there is a very large number of choice alternatives: 76. To deal with both of these problems, we followed the imputation approach of McFadden (1978), of which Train, McFadden, and Ben-Akiva (1987) is an example. For each observed consumer choice, we sampled with equal probability, nine other choice alternatives from the consumer's area of residence and add them to the chosen option. Hence, for each consumer, we created a choice set with ten alternatives, including his actual choice. The final data set consists of the choices of 3.243 individuals, and each individual has a set of ten alternative choices.

The imputation process of the non-observed choices created, potentially, an endogeneity problem. The prices of the non-chosen alternatives by a given consumer were imputed from observed choices made by other consumers in the sample. Some prices, e.g., involving discounts, may depend on the consumers' characteristics. As a consequence, the imputed

[16] See Haberman (1972) and Bishop, Fienberg, and Holland (1975).

prices might differ from those that would be observed, and the difference might depend on the characteristics of the consumers where the imputed data originated from. This can have an interpretation of an unobserved product attribute correlated with price.

We followed the control function (CF) approach to eliminate from the price effect this additional variability among the different alternatives, induced by the imputation mechanism. The control function approach encapsulates general methods of implementing an instrumental variables identification strategy in non-parametric and non-linear models. For an application of the control function approach in the context of discrete choice models see, e.g., Petrin and Train (2010). More generally see Blundell and Matzkin (2010), Powell and Blundell (2003) and the literature review on identification given by Matzkin (2007). In our case, as in Petrin and Train (2010), the control function is the residual of a regression of prices on the instruments. The instruments used are: **(i)** dummy variables for choice alternatives, in accordance with the choice alternative description of Section 5.1.2, **(ii)** dummy variables for region at the Nomenclature of Territorial Units for Statistics (NUTS) 3 level, **(iii)** interactions between dummy variables for region and choice alternative, whenever the number of variables allowed it, **(iv)** length of the contract, and **(v)** characteristics of the choice alternative described above and present on the utility function. These instruments capture the non-observed product quality differences, with the understanding of quality differences detailed above.

Finally, we note that this procedure also addresses sources of endogeneity from other unobserved product attributes correlated with price, for which the instruments defined above are valid.

5.3 Demand Estimates

Using the framework described in Section 4.1, namely the linear index for the utility in equation (2) as well as the choice probabilities defined in section 4.2, and the data described in Section 5.1, we estimated four models : **(i)** a MNL model with CF, **(ii)** a NL model with CF, **(iii)** a CNL model with CF and **(iv)** a CNL model without CF.

The variables included in vector $\mathbf{x}_{hs}$ are: **(i)** dummy variables for the type of bundle, namely double-play and triple-play, **(ii)** dummy variables for firms, **(iii)** characteristics of the services contained in each choice alternative, namely, number of television channels and bandwidth, and **(iv)** a dummy variable for fixed telephony. The number of television channels varies between 20 and 143, and the bandwidth varies between 1 and 100 Mbps.

Table 8 reports the results for the MNL, the NL and the CNL models.

[*Table* 8]

In the three models that include the CF, the estimate of the associated coefficient, labelled "CF", is statistically significant. In addition, in the CNL model without CF the estimate of the price coefficient is 25% smaller in absolute value than in the CNL with CF. This justifies the correction performed by the control function. From now on we will ignore model (iv) and make no reference to the CF when referring to the other three models.

Also in all models, the estimate of the coefficient of the price variable is negative and statistically significant, which implies negative sloping demand curves, in accordance with economic theory.

The price coefficient is fundamental to determine the price-elasticities of demand. The way this coefficient is reflected in the price-elasticity of demand helps the interpretation of its magnitude. The graphics in Figure 1 illustrate the distributions of the price-elasticity of demand of triple-play products per supplier for the CNL model.

$[Figure\ 1]$

In the NL and CNL models, when a choice alternative consisted of a triple-play bundle, it was included in the triple-play bundle nest; when a choice alternative included a double-play bundle, it was included in the double-play bundle nest; and when a choice consisted only of single-play products, it was included in the single-play nest. The purpose of this procedure was to capture the possible existence of different market segments where the substitutability among choice alternative of the same segment is higher than the substitutability of choice alternative of different segments.[17] The estimate of the coefficient of the double-play nest is not significantly different from 1. Consequently, its value was fixed at 1. There is a separate nest for the inexistence of any choice alternative, whose coefficient is normalized to 1.

In the CNL model we also considered firm nests. We present the estimates of the coefficients of firm nests for only three firms: f_1, f_2 and f_3. For the other firms, the coefficients of the firm nests were fixed at 1, because their estimates were not significantly different from that value.

For the latter model, the estimates of the coefficients of the nests we present are all significantly different from 1. This implies the rejection of the MNL model, as well as the NL model where only bundle nests are considered, and the NL model where only firm nests are considered. Since the estimates of the coefficients of the nests are all smaller than 1, they are consistent with economic theory.

Regarding the interpretation of the demand estimates, in any discrete choice model the consumers' valuation for the product attributes can be expressed in monetary terms by dividing the estimates of the associated coefficients by the marginal utility of income, here given by the negative of the estimate of the price coefficient. For numerical reasons, we rescaled the price by dividing it by the overall mean, 50.546€. Hence, the price coefficient should

[17] If the value of the coefficient of the nest is 0, the products in the nest are independent of the other products; if the value of the coefficient of the nest is 1, the products in the nest and outside the nest are equally substitutable.

also be rescaled by this factor. In addition, these monetary values should be interpreted as differences from the baseline, here of no product, or as differences between attributes. For example, the implicit valuation of firm f_2 relative to firm f_1 is $\frac{1.023-0.448}{1.054} \times 50.546 = 27.57$€. Likewise, a change from three single-play products, one from firm f_1 and two from firm f_2, to a triple-play product with the same characteristics but from firm f_2 has the valuation of $\frac{-0.877+1.350+1.023}{1.054} \times 50.546$€$= 71.74$€. Or, consumers value the single-play, fixed-line product of firm f_1 at a premium of $\frac{0.877-1.023+0.367}{1.054} \times 50.546$€$= 10.60$€ relative to the no product alternative.

For comparison purposes we also estimated a Mixed Logit (MMNL) model. The estimates are presented in Appendix B. We refer the reader to the Appendix B to a discussion of the results and a comparison with the estimates of the CNL model.

As a consequence of the previous discussion, we selected the CNL model to conduct our analysis in Section 6.

5.4 Elasticities

Next we present two sets of price elasticities of demand based on estimates of the CNL model of Table 8.[18] Table 9 presents the aggregate price elasticities of demand for triple-play products.

[*Table* 9]

The demand for triple-play products is elastic, with own-price elasticities for firms $f_1 - f_3$, the larger firms, ranging between 3.2 and 1.3.[19] The remaining firms, with smaller elasticities, in absolute value, have market shares smaller than $0,5\%$.

Table 10 presents the aggregate price elasticities of demand for the products in our sample.

[*Table* 10]

The market demand for triple-play is also elastic, but not much, with a market own-price elasticity of 1.4. Nevertheless, triple-play has the highest own-price elasticity of the products under analysis.

The demand for triple-play is less sensitive to the prices of the other products considered,

[18] These are the elasticities of demand of the products offered by the firms with respect to prices, not the elasticities of choice alternative with respect to its prices.

[19] The lower absolute values for the own-price elasticities of demand for some of the smaller firms apparently contradicts the underlying intuition of logit type models. However, these low values follow from the reported values being averages over individuals. For consumers who have this product in their consideration set, the probability of choice may be high, leading to a low elasticity in absolute value. However, there are many consumers for whom the product is not even in their consideration set. As a consequence, the overall market share is small.

than the demand of those other products is sensitive to the price of triple-play. This reflects an asymmetric competitive pressure between the different products.

Table 10 shows that a product A tends to be a complement of, or have a low substitutability with, products that include services that product A lacks. For example, the double-play product of fixed voice and fixed broadband is a complement of the single-play product of subscription television.[20] Similarly, the single-play product of fixed voice is a complement of the single-play product of subscription television and of the single-play product of fixed broadband.

6 SSNIP Test

This Section presents the three versions of the SSNIP test. Appendix A contains the details of the implementation.

6.1 UPI Version

Next, we present the profit variations that would occur if a hypothetical monopolist increased the prices of its products by 5% and by 10%. Table 11 displays the results.

[*Table* 11]

As shown in columns "$\Delta\pi_5$" and "$\Delta\pi_{10}$", for all sets of triple-play products reported, price increases of 5% and 10% are profitable.[21]

6.2 EPI Version

Next, we present the percentage price variations that would occur as one moves from a market structure where each firm controls one product, to market structures where the hypothetical monopolist controls an increasing number of triple-play products. This corresponds to the EPI version of the SSNIP test. Table 11 displays the results.

As shown in column "$\frac{\Delta p}{p}_{(s)}$", a hypothetical monopolist that controlled all triple-play products, would, in equilibrium, increase, on average, the price of those products by 12.8%,

[20] Excluding extreme parameter values, typically discrete choice models do not allow for complementarity. We obtain complementarity because the definition of choice alternatives proposed includes more than one product per choice alternative and the price is the sum of the prices of the products included.

[21] In broad terms, the result of a SSNIP test for a set products depends on: **(i)** the price sensitivity, i.e., the own-price elasticities of demand, and **(ii)** the substitution pattern, i.e., the cross-price elasticities of demand. The lower, in absolute value, the own-price elasticities are, the more likely it is that raising the products' prices is profitable. Similarly, the lower the cross-price elasticities between those products and the remaining products are, the more likely it is that raising their prices is profitable.

compared to the case where each triple-play product, as well as the other products, is controlled by a different firm.

We analyzed, for the EPI version, the sensitivity of the results of the SSNIP test with respect to the uncertainty implicit in the estimates of the demand model. For this purpose, we built confidence intervals for the price variation by generating 100 vectors of parameters of the demand function with a joint normal distribution with an average equal to the estimate of the parameters and a variance-covariance equal to the estimated variance-covariance. For each of these parameter vectors we computed the price variation caused by a hypothetical monopolist. From this exercise we obtained a 95% confidence interval of the estimated value for the price variation, presented in the column labeled "CI" of Table 11.[22]

For example, a hypothetical monopolist controlling the triple-play products of all firms could raise prices, in equilibrium, by 12.8% with a 95% confidence interval of $[11.27\%, 14.33\%]$.

6.3 UPP Version

Next we present the UPP version of the SSNIP test, displayed in Table 11.

As shown in column "$\frac{\Delta p}{p}_{(u)}$", a hypothetical monopolist that controlled all triple-play products would, in equilibrium, increase, on average, the prices of those products by 16.5%, compared to the case where each triple-play product, as well as the other products, is controlled by a different firm.

6.4 Policy Discussion

According to all three versions of the SSNIP test performed, triple-play products are a relevant product market in the sense of competition policy. Next we discuss some of the implications of this result.[23]

The current practice in the telecommunications industry, both for regulatory and competition proceedings, is to consider only relevant markets for individual services.

Regarding regulatory proceedings, the EC's Recommendation on relevant product markets within the electronic communications sector susceptible to ex ante regulation of 2007 indicated that the retail markets related to the wholesale markets susceptible to ex ante regulation were: for fixed voice, the retail markets for local and national calls; for broad-

[22] In principle, one could re-estimate the model used and the SSNIP price variation for several bootstrap samples and obtain, as a result, confidence intervals that also take into account the effect of the sampling variation in the SSNIP test.

[23] This does not preclude the possibility that there may be also other relevant product markets for the various combinations of the components of triple-play products. As it is well known product markets may overlap.

band, the retail market of broadband internet access; and for subscription television, the retail market of television broadcasting. The Recommendation conditioned the market delineations processes in all EU countries, which in general simply followed the proposed list of product markets. Even as late as 2010, Ofcom, the UK telecommunications sectoral regulator, in its review of the wholesale broadband access markets defined retail broadband as a relevant product market.

Regarding competition proceedings, the EC has also followed the practice of only considering individual communication services as relevant product markets. For instance, in the recent abuse of dominance case COMP/39.525 - Telekomunikacja Polska, the relevant product market considered was retail fixed broadband Internet access services. In addition, in the recent merger case COMP/M.5730 - Telefonica/ Hansenet Telekommunikation, the relevant markets considered were: retail fixed broadband access to residential customers and small business customers, the retail fixed broadband access to large business customers, and the local and international fixed-line telephony services for residential and non-residential customers.

In the US the Federal Communications Commission (FCC) has followed a similar approach. In the recent merger cases of Comcast-NBCU and Verizon Wireless-SpectrumCo, the FCC had some consideration for the effect on competition of triple-play and quadruple-play bundles.[24] However, the FCC never publicly defined triple-play or quadruple-play products as a relevant product market in the analysis of these transactions.

As the importance of bundles of telecommunication services grows, the question of whether these new products constitute separate relevant markets has been raised several times. Already in 2007, in its Recommendation, the EC stated that many telecommunications services were sold as bundles, which in the future could become separate relevant product markets. It referred as an example the case of the double-play bundle of fixed broadband and subscription television, which was yet at an early stage of development. Later, in 2010, the Body of European Regulators on Electronic Communications (BEREC) published a report about the impact of bundles in the delineation of retail and wholesale markets: BEREC (2010). The report argued that since bundling was becoming an increasingly popular way of buying and selling communication services, it was important to analyze the impact of bundling on market definition. The report considered several possible market configurations, which included the cases where bundles and individual services constitute separate markets, and the case where bundles and individual services are included in the same markets.

There have been a few attempts to determine whether bundles of telecommunications services, e.g., triple-play bundles, constitute separate relevant product markets. Ofcom in its 2010 review of the wholesale broadband access market argued that consumers have no

[24] See, respectively, case "WT Docket 12-4 - Verizon Wireless and SpectrumCo" and case "MB Docket No. 10-56 - Comcast Corporation and NBC Universal".

intrinsic preference for bundles and buy them merely looking for savings. Hence, they are likely to respond to price differentials by switching from bundles to their individual components. Based on this argument Ofcom concluded that there was not enough evidence that bundles of telecommunications services constitute separate product markets. The Dutch sectoral regulator and the Hungarian Competition Authority commissioned consumer surveys to determine if triple-play bundles constituted relevant product markets.[25] In both cases consumers were asked if they would switch from bundles to their individual components if compensated with various levels of price savings. The Dutch survey concluded that a large number of consumers was prepared to give up a bundle for a 10% price reduction, whereas the Hungarian survey concluded the opposite. Based on these results the Dutch and Hungarian studies drew opposite conclusions on whether triple-play bundles are a relevant product market. Note, however, that neither the Ofcom thought experiment or the Dutch and Hungarian surveys constitute SSNIP tests.

Determining if bundles of telecommunications services constitute a relevant product market, or on the contrary only products consisting of individual services constitute relevant product markets, has several important implications for the intervention of sectoral regulators and competition authorities in the industry.

In regulatory proceedings in the EU usually only wholesale markets are regulated. However, the evaluation of whether a wholesale market is competitive is made with reference to the associated retail market. If it is established at the retail level that bundles constitute a relevant product market, then it may be appropriate to define a relevant product market for bundles at the wholesale level, which in turn requires re-examining which markets are susceptible of ex ante regulation, or which regulatory mechanisms are the most adequate. See BEREC (2010) for a discussion of these issues.

In abuse of dominance cases, depending on which markets the competition analysis is framed, a given firm may be found to be dominant or not, and hence a given conduct may be found to be anticompetitive or not. A recent case in Portugal illustrates this point. Until recently the Portuguese Competition Authority (PCA) only considered markets of individual telecommunications services. However, after two complaints regarding triple-play bundles, the PCA conducted a study to analyze if these products constituted a relevant product market. The study found that in Portugal triple-play bundles were a relevant product market. This had an impact in the PCA's decision, since dominant positions changed considerably depending on which relevant product markets were considered. If fixed voice services were the relevant product market, f_1 was potentially a dominant firm, whereas if subscription television services were the relevant product market, then f_2 was potentially a dominant firm. However, if the triple-play bundles, that include the two former services plus fixed broadband services, were the relevant product market, it was unclear whether there was dominance by any firm at all. Hence, depending on which relevant product markets

[25] See Pápai, Lorincz, and Édes (2011).

were considered, the alleged conducts underlying the complaints filled with the PCA could have been considered anticompetitive or not.

Similarly in merger review cases, depending on which relevant product markets are considered, a given merger may be found to substantially lessen competition or not.

7 Robustness

This Section discusses the robustness of the results of the SSNIP test with respect to: **(i)** the model specification, and **(ii)** the geographic market. In addition we also discuss portfolio effects.

7.1 Demand Model

Table 12 presents the results of the UPI, EPI and UPP versions of the SSNIP test for the MNL and NL models of Table 8.

[*Table* 12]

The value of the estimated profit and price variations changes with the MNL model and the NL model with bundle nests. However, qualitatively, the conclusion of the SSNIP test does not change. Consider, for example, the NL model with bundle nests. A hypothetical monopolist that controlled all triple-play products, would, in equilibrium, increase, on average, the price of those products by 11.6%, compared to the case where each triple-play product, as well as the other products, is controlled by a different firm.

7.2 Geographic Market

We investigated whether competition conditions regarding triple-play products vary across regions within the country. For this purpose, we estimated demand models for the five NUTS 2 regions of the country. We chose to conduct the analysis at the NUTS 2 level to ensure that the samples of all regions were representative. However, it is unclear to us whether NUTS 2, NUTS 3 or the central office are the correct level to conduct the analysis. Hence, the analysis of this Section should be seen as an illustration of how this methodology can be applied to the delineation of the geographic market.

Figure 2 plots the coefficient estimates for the NL model with bundle nests.[26] For comparison purposes, we also plot in red the estimates of the country level model of Table

[26] The sample sizes of some of the regions did not allow a numerical identification of the CNL model.

8. Vertical lines depict 95% confidence intervals.

[*Figure* 2]

The regional coefficients are, by and large, the same as the country level ones. In fact, a likelihood ratio test does not reject the null hypothesis that they are all equal. We also note that given the smaller sample sizes many more of the coefficients are not statistically different from zero. This exercise does not reveal a substantial variation in the competition conditions across regions at the NUTS 2 level.

Given the data collected, a more detailed construction of samples at a regional level could be carried out. This would obviate some of the size problems of the regional samples.

7.3 Portfolio Effects

We implemented the SSNIP test assuming that: **(i)** initially each firm controlled only one product, and **(ii)** the hypothetical monopolist controls only triple-play products. In particular, we excluded the possibility that the hypothetical monopolist might control several types of products, namely the individual products that constitute triple-play bundles. Ignoring these portfolio effects corresponds to the approach usually considered in the literature and by Competition Authorities when analyzing markets of individual products.

It might seem awkward to allow a firm to offer bundles of services, but prevent it from offering also the services that constitute those bundles. However, that is the correct procedure to determine if a set of bundles constitutes a relevant product market. Suppose, to the contrary, that initially each triple-play product is controlled by a different firm. In addition, each of these firms controls also the individual products and double-play products associated with its triple-play product. Suppose now that the sets of products of two of these initial firms are controlled by a hypothetical monopolist. In this context, a SSNIP test evaluates whether the hypothetical monopolist has market power with respect to ***all*** of its products, and not specifically with respect ***only*** to triple-play products, which is what one is interested in knowing.

By ignoring portfolio effects, typically, one under-estimates the market power of the hypothetical monopolist, since there is potentially some substitutability between triple-play bundles and these other products or their combinations. Hence, when the result of the SSNIP test is positive, as in our case, if for some reason one included portfolio effects in the analysis, the results would remain qualitatively unchanged.

8 Conclusion

In the presence of bundles, market delineation and competition analysis are likely to become more complex for a number of reasons. First, estimating the demand for bundles, as well as individual products, may be challenging. Second, a relevant product market may consist of a set of products of the same type, e.g., of triple-play products, or of a set of products of different types, e.g., of triple-play products plus double-play and even single-play products. When the latter occurs, the issue of which path to follow when conducting a SSNIP test becomes non-trivial, and the results may be very sensitive to the particular path chosen. Third, for a given set of individual services, several relevant product markets for different types of bundles or products may coexist, with dominance differing across these markets. Under these circumstances, the result of competition analysis may depend on the market on which the inquiry is framed.

In spite of the these difficulties, both market delineation and competition analysis can still be performed in the presence of bundles using the traditional tools of competition policy. Indeed, this article showed how the SSNIP test can be extended to bundles and illustrated the procedure with triple-play products.

We collected a unique invoice based consumer level data set from Portuguese telecommunications firms. An adequate definition of choice alternatives allowed us to cast within the discrete choice framework the consumer's choice problem and estimate coherently the demand for bundles and individual products. With these demand estimates, we performed three versions of the SSNIP test, all of which point to the conclusion that, in Portugal, triple-play products are a relevant product market.

Our article sheds light on the discussion about the impact of bundles on competition and regulatory policy in the telecommunications industry. Bundles may constitute separate relevant markets. Future competition and regulatory proceedings should consider the potential existence not only of markets of products consisting of individual services, but also of markets of products consisting of bundles of services, namely of triple-play products. This implies that the number of markets under consideration may increase. In addition, it implies that the competition analysis for bundles should be framed on those markets and not on the markets of the associated individual products. But more importantly, as the focus of the analysis shifts from markets of individual products to markets of bundles, the underlying competition analysis may change considerably. In particular, the identity of the dominant firms may change.

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A Appendix A: SSNIP Test

A.1 Notation

Suppose that there are $i = 1, ..., N$ product candidates to belong to the relevant product market. Denote by p_i, the price of product i, by $y_i = D_i(\mathbf{p})$, the demand for product i, and by c_i, the constant marginal cost of product i. Let $\mathbf{p} := (p_1, \ldots, p_N)'$, $\mathbf{y} := (y_1, ..., y_N)'$ and $\mathbf{c} := (c_1, ..., c_N)'$.

The profit of product i is:

$$\pi_i = (p_i - c_i)\, D_i(\mathbf{p}).$$

The profit of firm $f = 1, ..., F$, which controls the set of products Ω_f is:

$$\Pi_f = \sum_{i \in \Omega_f} (p_i - c_i)\, D_i(\mathbf{p}).$$

The first-order condition for profit maximization with respect to prices for firm f is:[27]

$$\frac{\partial \Pi_f}{\partial p_i} = D_i(\mathbf{p}) + \sum_{j=1}^{N} \gamma_{ij} \frac{\partial D_j(\mathbf{p})}{\partial p_i} (p_j - c_j) = 0. \tag{5}$$

where γ_{ij} is a parameter such that $\gamma_{ij} = 1$, if products i and j are controlled by firm f, and $\gamma_{ij} = 0$ otherwise.

Let matrices Γ and Φ consist of the elements $\Gamma_{ij} := \gamma_{ij}$ and $\Phi_{ij} := \frac{\partial D_j(\mathbf{p})}{\partial p_i}$, respectively. Matrix Γ represents the property structure, and matrix Φ consists of the demand estimates. Denote by $A \circ B$ the element by element product of matrices A and B, i.e., the Hadamard product. The system that defines the market equilibrium can be written in matrix form as:

$$\mathbf{y} + (\Gamma \circ \Phi)(\mathbf{p} - \mathbf{c}) = 0. \tag{6}$$

A.2 Unilateral Price Increase

Suppose that initially each product is controlled by a different firm, and that the initial equilibrium prices are $p_1^0, ..., p_N^0$. Let $\mathbf{p}^0 := (p_1^0, \ldots, p_N^0)$. Suppose now that products $\Omega_m = \{1, 2\}$ are controlled by a hypothetical monopolist. Denote by $\mathbf{p}_m^0 = (p_1^0, p_2^0)$, the vector of the initial equilibrium values of the prices of products Ω_m, and denote by $\mathbf{p}_{-m}^0$, the vector of the initial equilibrium values of the remaining products. Let the hypothetical monopolist raise its prices by 5% or 10%, which then take values $\mathbf{p}_m^1 := (p_1^1, p_2^1)$.

[27] We assume that a Nash equilibrium exists for strictly positive prices. Caplin and Nalebuff (1991) proved existence in a general discrete choice model, with single product firms. Anderson and de Palma (1992) proved existence for the nested logit model with symmetric multiproduct firms.

The profit variation for the hypothetical monopolist caused by the increase in prices $\mathbf{p}_m^1$ is:

$$\Delta\Pi_m = \sum_{i\in\Omega_m} \left[(p_i^1 - c_i)D_i(\mathbf{p}_m^1, \mathbf{p}_{-m}^0) - (p_i^0 - c_i)D_i(\mathbf{p}^0)\right].$$

If the profit variation of the hypothetical monopolist is positive, $\Delta\Pi_m > 0$, products $\{1,2\}$ constitute a relevant product market; otherwise the exercise should be repeated with the hypothetical monopolist controlling a larger set of products, namely $\{1,2,3\}$.

The ***relevant product market*** is the smallest set of products whose price could be increased profitably by a hypothetical monopolist, i.e., the smallest set Ω_m for which $\Delta\Pi_m > 0$.

Next we discuss the information required to implement this version of the test.[28]

Current prices, $\mathbf{p}^c$, current quantities, $\mathbf{y}^c$, and the current property structure, Γ^c, are observed.

Demand functions $D_i(\cdot)$ are described in Section 4. The estimates of the parameters of the demand function, obtained using the data described in 5.1.1, are presented in Section 5.3.

Marginal costs are estimated as follows. Assume that the current observed scenario is one of equilibrium. Substitute the current prices, $\mathbf{p}^c$, the current property structure, Γ^c, and the estimates of the demand function, $\hat{\Phi}$, in the system of equations (6). Afterwards, solve the system in order to $\mathbf{c}$, to obtain the estimates of marginal costs, $\hat{\mathbf{c}}$.

Initial prices, $\mathbf{p}^0$, are estimated as follows. Substitute the estimates of the parameters of demand function, $\hat{\Phi}$, and the estimates of marginal costs, $\hat{\mathbf{c}}$, in the system of equations (6). Let $\Gamma = I_N$. Afterwards, solve the system in order to prices to obtain, $\mathbf{p}^0$.

A.3 Equilibrium Price Increase

Suppose that initially each product is controlled by a different firm, and that the initial equilibrium prices are $p_1^0, ..., p_N^0$. Let $\mathbf{p}^0 := (p_1^0, \ldots, p_N^0)$. Suppose now that products $\Omega_m = \{1,2\}$ are controlled by a hypothetical monopolist, and that the equilibrium prices of this new market are $p_1^1, ..., p_N^1$. Let $\mathbf{p}^1 := (p_1^1, \ldots, p_N^1)$.

If the average of prices (p_1^1, p_2^1) is higher than the average of prices (p_1^0, p_2^0) by at least 5% or 10%, products $\{1,2\}$ constitute a relevant product market; otherwise the exercise should be repeated with the hypothetical monopolist controlling a larger set of products, namely $\{1,2,3\}$.

The ***relevant product market*** is the smallest set of products whose prices, in equilibrium are, on average, at least 5% or 10% higher, if controlled by a hypothetical monopolist,

[28] For more details on the procedure see, e.g., Nevo (2000) or Pereira and Ribeiro (2011).

than if controlled by separate firms.

Both the initial equilibrium prices $\mathbf{p}^0$ and the new equilibrium prices $\mathbf{p}^1$ are obtained from the system of equations (5), through the process described in Section A.2, by adjusting appropriately matrix Γ to reflect the different property structures.

A.4 Upward Pricing Pressure

Suppose that initially all products are controlled by different firms, and that the initial equilibrium prices are $p_1^0, ..., p_I^0$. Suppose now that products $\Omega_m = \{1, 2\}$ are controlled by a hypothetical monopolist. However, products Ω_m belong to separate divisions of the hypothetical monopolist, division 1 and 2, respectively. Each division chooses its prices to maximize only its divisional profit, therefore ignoring the impact of its decision on the other division's profit. Management of the hypothetical monopolist wants to set prices that maximize joint profits, which current prices do not, and wants to do so in a decentralized manner. One first step to achieve this would be to impose a tax, τ_1, on division 1's quantities that internalizes the cannibalization of division 2's profits. Such a tax would equate the first-order condition of division 1's profits with respect to p_1 to the first-order conditions of joint profits with respect to p_1:

$$D_1(\mathbf{p}) + \frac{\partial D_1(\mathbf{p})}{\partial p_1}(p_1 - c_1 - \tau_1) = D_1(\mathbf{p}) + \sum_{j=1,2} \frac{\partial D_j(\mathbf{p})}{\partial p_1}(p_j - c_j),$$

from which we obtain:

$$\tau_1 = -\frac{\frac{\partial D_2(\mathbf{p})}{\partial p_1}}{\frac{\partial D_1(\mathbf{p})}{\partial p_1}}(p_2 - c_2).$$

A symmetric tax τ_2 would be imposed on division 2's quantity.

Taxes τ_i can be interpreted as the upward pricing pressure on price i induced by the joint optimization of profits by the hypothetical monopolist. Values (τ_1, τ_2) are an approximation of the average equilibrium variation of prices (p_1^1, p_2^1) of Section A.3, and the same exercise detailed there can be done with this approximation.

B Appendix B: Mixed Logit Model

An alternative to the CNL model in the way of modeling the choice probabilities, allowing for different substitution patterns between the choice alternatives under analysis, is to consider that the unobserved component of the utility function has a distribution which is a mixture between an extreme value type I error term and a multivariate Gaussian, yielding the MMNL model. In this case, errors ε_{hs} are independently and identically distributed across households and choice alternatives, and follow an extreme value type I distribution. In addition:

$$\theta_h := \theta + \mathbf{L}_\theta \zeta_h,$$

where $\mathbf{L}_\theta$ is a lower triangular matrix of the appropriate dimension, and ζ_h follows the distribution $\mathcal{N}(0, I)$, i.e., θ_h is normally distributed with mean $\boldsymbol{\theta}$ and variance-covariance $\mathbf{L}_\theta \mathbf{L}'_\theta$. We restrict $\mathbf{L}_\theta$ to be diagonal. Ignoring the subscript h the probability of choice alternative s from set $\mathcal{C}$ being chosen is given by:

$$P(s|\mathcal{C}) = \int \frac{\exp(V_s(\boldsymbol{\zeta}))}{\sum_t \exp(V_t(\boldsymbol{\zeta}))} \Phi(\boldsymbol{\zeta}) d\boldsymbol{\zeta}.$$

For comparison purposes we also estimated a MMNL model.[29] Table 13 presents the estimates.

[$Table$ 13]

The random terms associated with the dummy variables that define the nests can be seen as generating correlation between the products within that nest, therefore a similar effect to the one that occurs in nested and cross-nested models. The MMNL model presented has additional random terms associated to other characteristics, namely price. The small standard error associated with the standard deviation of the price coefficient suggests that there is heterogeneity in price sensitivity amongst consumers. Nevertheless, this model despite having more coefficients has a lower likelihood than the CNL model of Table 8.[30]

[29]The MMNL model was estimated using maximum simulated likelihood with Halton draws.

[30]In addition, the imputation process we follow to deal with the non-observability of the choice set, following Train, McFadden, and Ben-Akiva (1987), induces an additive shift in the linear index component if the model is correctly specified as being in the GEV family. This linear shift cancels out if the sampling probabilities for the alternatives in the choice set are chosen appropriately. This property is not verified in the MMNL as it is not a member of the GEV class. See Bierlaire, Bolduc, and McFadden (2008) for a discussion.

C Tables

Table 1: Market shares

	Fixed voice		Pay-TV		Broadband	
	2008	2009	2008	2009	2008	2009
PT	65.7%	61.6%	13.6%	23.0%	41.6%	44.5%
ZON	4.4%	10.2%	72.3%	64.4%	31.3%	32.2%
Optimus	16.3%	14.5%	0.5%	1.0%	12.5%	9.2%
Vodafone	5.1%	6.1%	-	0.3%	2.8%	3.9%
Cabovisão	3.3%	3.6%	12.4%	10.2%	9.3%	8.0%
AR Telecom	1.7%	1.4%	1.0%	0.9%	1.5%	1.4%
Others	0.7%	0.5%	0.1%	0.1%	1.0%	0.8%

Market share in terms of subscribers, except for fixed telephony which is in terms of traffic. Source: ICP-ANACOM (Relatórios trimestrais)

Table 2: Average monthly net payments

	Bundles				
Services	no b	FV+TV	FV+BB	TV+BB	FV+TV+BB
FV	10.7	0.0	0.0	0.0	0.0
TV	40.5	0.0	0.0	0.0	0.0
BB	23.9	0.0	0.0	0.0	0.0
FV+TV	52.3	53.4	0.0	0.0	0.0
FV+BB	34.8	0.0	23.4	0.0	0.0
TV+BB	66.0	0.0	0.0	69.1	0.0
FV+TV+BB	76.0	73.7	64.1	74.2	55.9

Source: Authors' calculations

Table 3: Products - Notation

Services

N	Notation	Description
1	000	no serv.
2	100	FV
3	010	TV
4	001	BB
5	110	FV+TV
6	101	FV+BB
7	011	TV+BB
8	111	FV+TV+BB

Bundles

N	Notation	Description
1	p000	no serv.
2	no b	No bundle - Single play
3	p110	Double play FV+TV
4	p101	Double play FV+BB
5	p011	Double play TV+BB
6	p111	Triple play FV+TV+BB

Firms

N	Notation
1	f_0
2	f_1
3	f_2
4	f_3
5	f_4
6	f_5
7	f_6

Table 4: Products - Examples

N	Services	Bundles	S. FV	S. TV	S. BB	Description
0	000	p000				No services
1	100	no b	f_1			Fixed voice from f_1
2	111	p111	f_2	f_2	f_2	Triple-play from f_2
3	010	no b		f_2		Pay-TV from f_2
4	111	p111	f_1	f_1	f_1	Triple-play from f_1
5	101	p101	f_4		f_4	Double play (FV+BB) from f_4
6	110	no b	f_1	f_2		Fixed voice from f_1 + Pay-TV from f_2
...						

S. FV - supplier of FV; S. TV - supplier of TV; S. BB - supplier of BB

Table 5: Services vs. bundles

	Bundles						
Services	p000	no b	p110	p101	p011	p111	Total
000	[26-28%]	0%	0%	0%	0%	0%	[26-28%]
100	0%	[14-16%]	0%	0%	0%	0%	[14-16%]
010	0%	[10-12%]	0%	0%	0%	0%	[10-12%]
001	0%	[0-2%]	0%	0%	0%	0%	[0-2%]
110	0%	[4-6%]	[4-6%]	0%	0%	0%	[10-12%]
101	0%	[0-2%]	0%	[4-6%]	0%	0%	[4-6%]
011	0%	[0-2%]	0%	0%	[4-6%]	0%	[6-8%]
111	0%	[0-2%]	0%	[2-4%]	[0-2%]	[16-18%]	[22-24%]
Total	[26-28%]	[36-38%]	[4-6%]	[6-8%]	[4-6%]	[16-18%]	100%

Distribution of services consumed per type of bundle, 2009. Source: ICP-ANACOM, "Inquï£¡rito ao consumidor"

Table 6: Distribution and market shares

	FV		TV		BB	
	Dist.	MkS	Dist.	MkS	Dist.	MkS
no serv.	[44-46%]	-	[48-50%]	-	[62-64%]	-
f_1	[30-40%]	[50-60%]	[10-20%]	[20-30%]	[10-20%]	[30-40%]
f_2	[0-10%]	[10-20%]	[20-30%]	[50-60%]	[10-20%]	[20-30%]
f_3	[0-10%]	[0-10%]	[0-10%]	[10-20%]	[0-10%]	[0-10%]
f_4	[0-10%]	[10-20%]	[0-10%]	[0-10%]	[0-10%]	[10-20%]
f_5	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]
f_6	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]

Distribution of market shares (regarding the number of clients) per service, 2009. Source: data from operators

Table 7: Distribution and market shares per bundle

	p110		p101		p011		p111	
	Dist.	MkS	Dist.	MkS	Dist.	MkS	Dist.	MkS
no serv.	[94-96%]	-	[92-94%]	-	[94-96%]	-	[92-94%]	-
f_1	[0-10%]	[40-50%]	[0-10%]	[0-10%]	[0-10%]	[30-40%]	[0-10%]	[30-40%]
f_2	[0-10%]	[30-40%]	[0-10%]	[0-10%]	[0-10%]	[50-60%]	[0-10%]	[40-50%]
f_3	[0-10%]	[20-30%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[10-20%]
f_4	[0-10%]	[0-10%]	[0-10%]	[80-90%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]
f_5	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]
f_6	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]	[0-10%]

Distribution of market shares (regarding the number of clients) per type of bundle, 2009. Source: data from operators

Table 8: Demand Models - I

	Logit			Nested			Cross-Nested			Cross-Nested No CF		
Variable	Coef.		St. Err.	Coef.		St. Err.	Coef.		St. Err.	Coef.		St. Err.
single	1.509	***	0.086	1.382	***	0.126	0.877	***	0.116	0.849	***	0.088
dual	0.531	***	0.098	0.174		0.112	-0.148		0.132	-0.158		0.107
triple	2.073	***	0.123	1.768	***	0.153	1.350	***	0.145	1.296	***	0.110
f_1	-1.174	***	0.073	-0.929	***	0.093	-1.023	***	0.093	-1.070	***	0.083
f_2	-0.136	*	0.073	-0.003		0.014	-0.448	***	0.103	-0.438	***	0.076
f_3	-0.204	*	0.112	-0.026		0.094	-0.471	***	0.125	-0.792	***	0.115
f_4	-2.284	***	0.144	-1.981	***	0.215	-2.298	***	0.165	-2.213	***	0.155
f_5	-3.676	***	0.116	-2.974	***	0.163	-3.457	***	0.168	-3.411	***	0.128
f_6	-3.905	***	0.227	-3.494	***	0.271	-3.795	***	0.250	-3.894	***	0.282
# channels	-0.019		0.034	-0.000		0.000	0.032		0.041	-0.028		0.022
bandwidth	-0.008		0.037	-0.029		0.051	-0.028		0.033	-0.068	***	0.039
fixed voice	0.522	***	0.062	0.497	***	0.097	0.367	***	0.061	0.349	***	0.055
CF	0.569	***	0.087	0.536	***	0.107	0.462	***	0.112			
price	-1.347	***	0.091	-1.232	***	0.098	-1.054	***	0.127	-0.786	***	0.070
nest(single)				0.703	***	0.039	0.166	***	0.055	6.248	***	1.479
nest(triple)				0.859		0.14	0.520	**	0.241	1.772	***	0.657
nest(f_1)							0.453	***	0.058	2.282	***	0.323
nest(f_2)							0.984		0.147	1.037	***	0.129
nest(f_3)							0.637	**	0.145	1.517	***	0.271
Log Lik	5580			5557			5501			5514		
Pseudo R2	0.294			0.297			0.304			0.304		
N	3432			3432			3432			3432		

Values reported under "Log Lik" are the negative of the likelihood function. ***, ** and * represent significance at 1%, 5% and 10% confidence levels respectively. The null hypothesis for the nest parameters is that they are equal to 1.

Table 9: Elasticity I

		∂p					
		f_1	f_2	f_3	f_4	f_5	f_6
	f_1	-2.029	0.339	0.257	0.005	0.000	0.005
	f_2	0.304	-1.304	0.171	0.004	0.000	0.004
∂Q	f_3	0.284	0.211	-3.151	0.004	0.000	0.004
	f_4	0.107	0.103	0.082	-0.948	0.000	0.004
	f_5	0.080	0.087	0.070	0.004	-0.403	0.004
	f_6	0.106	0.102	0.082	0.004	0.000	-1.036

Price elasticities of triple play products offered by firms. Elasticities presented are weighted averages of individual price elasticities.

Table 10: Elasticity II

		∂p						
		111	110	101	011	100	010	001
∂Q	111	-1.352	0.073	0.015	0.091	0.050	0.225	0.101
	110	0.243	-1.143	0.015	0.076	0.038	0.163	0.017
	101	0.235	0.070	-0.452	0.075	0.035	-0.176	0.075
	011	0.284	0.072	0.015	-1.137	0.010	0.199	0.086
	100	0.340	0.075	0.015	0.020	-0.789	-0.145	-0.016
	010	0.323	0.074	-0.016	0.091	-0.031	-0.834	0.045
	001	0.314	0.022	0.015	0.085	-0.005	0.071	-0.343
	000	0.233	0.070	0.015	0.074	0.035	0.154	0.075

Price elasticities of types of products offered by firms. Elasticities presented are weighted averages of individual price elasticities.

Table 11: SSNIP Test

	Cross-Nested				
	$\Delta\pi_5$	$\Delta\pi_{10}$	$\frac{\Delta p}{p}_{(u)}$	$\frac{\Delta p}{p}_{(s)}$	CI
f_1+f_2	$\nearrow$	$\nearrow$	10.9	6.9	[5.7,8.1]
$f_1+f_2+f_3$	$\nearrow$	$\nearrow$	13.0	8.7	[7.3,10.1]
$f_1+f_2+f_3+f_4$	$\nearrow$	$\nearrow$	15.1	10.9	[9.4,12.4]
$f_1+f_2+f_3+f_4+f_5$	$\nearrow$	$\nearrow$	15.1	12.4	[10.9,13.9]
$f_1+f_2+f_3+f_4+f_5+f_6$	$\nearrow$	$\nearrow$	16.5	12.8	[11.3,14.3]

Each line corresponds to a set of products controlled by a hypothetical monopolist. For example, sign f_1+f_2refers to a hypothetical monopolist that controls the triple-play bundles of firms f_1 and f_2. Columns labeled $\Delta\pi_5$ and "$\Delta\pi_{10}$" indicate, whether a price increase of 5% and 10%, respectively, would increase or decrease the hypothetical monopolist's profits. The column labeled $\frac{\Delta p}{p}_{(u)}$ indicates the UPP price variation and the column labelled $\frac{\Delta p}{p}_{(s)}$ indicates the equilibrium price variation. Finaly the column labelled CI indicates a 95% confidence interval of $\frac{\Delta p}{p}_{(s)}$ obtained by bootstrap.

Table 12: SSNIP Test - 2

	Logit				Nested			
	$\Delta\pi_5$	$\Delta\pi_{10}$	$\frac{\Delta p}{p}_{(u)}$	$\frac{\Delta p}{p}_{(s)}$	$\Delta\pi_5$	$\Delta\pi_{10}$	$\frac{\Delta p}{p}_{(u)}$	$\frac{\Delta p}{p}_{(s)}$
f_1+f_2	$\nearrow$	$\searrow$	6.0	4.1	$\nearrow$	$\searrow$	6.8	4.7
$f_1+f_2+f_3$	$\nearrow$	$\nearrow$	7.6	5.4	$\nearrow$	$\nearrow$	8.8	6.3
$f_1+f_2+f_3+f_4$	$\nearrow$	$\nearrow$	10.0	7.7	$\nearrow$	$\nearrow$	11.3	8.9
$f_1+f_2+f_3+f_4+f_5$	$\nearrow$	$\nearrow$	11.2	9.1	$\nearrow$	$\nearrow$	13.1	11.1
$f_1+f_2+f_3+f_4+f_5+f_6$	$\nearrow$	$\nearrow$	11.6	9.5	$\nearrow$	$\nearrow$	13.5	11.6

Each line corresponds to a set of products controlled by a hypothetical monopolist. For example, sign f_1+f_2refers to a hypothetical monopolist that controls the triple-play bundles of firms f_1 and f_2. Columns labeled $\Delta\pi_5$ and "$\Delta\pi_{10}$" indicate, whether a price increase of 5% and 10%, respectively, would increase or decrease the hypothetical monopolist's profits. The column labeled $\frac{\Delta p}{p}_{(u)}$ indicates the UPP price variation and the column labelled $\frac{\Delta p}{p}_{(s)}$ indicates the equilibrium price variation.

Table 13: Demand Models - II

	Mixed Logit					
Variable	Mean	St. Err.		St. Dev.	St. Err.	
single	2.039	0.152	***	0.005	0.052	
dual	0.966	0.217	***	1.086	0.401	***
triple	3.132	0.244	***	2.225	0.475	***
f_1	-1.176	0.118	***	0.022	0.048	
f_2	0.029	0.105		0.024	0.062	
f_3	-0.978	0.267	***	1.205	0.377	***
f_4	-2.761	0.262	***			
f_5	-3.854	0.173	***			
f_6	-4.942	0.454	***			
# channels	-0.156	0.058	***	0.567	0.110	***
bandwidth	-0.985	0.179	***	1.526	0.201	***
fixed voice	0.402	0.086	***	0.297	0.273	
CF	0.367	0.132	***	0.069	0.046	
price	-1.451	0.151	***	0.991	0.204	***
Log Lik	5515					
Pseudo R2	0.302					
N	3432					

Values reported under "Log Lik" are the negative of the likelihood function. ***, ** and * represent significance at 1%, 5% and 10% confidence levels respectively.

D Figures

Figure 1: Triple-play elasticities - distribution per operator

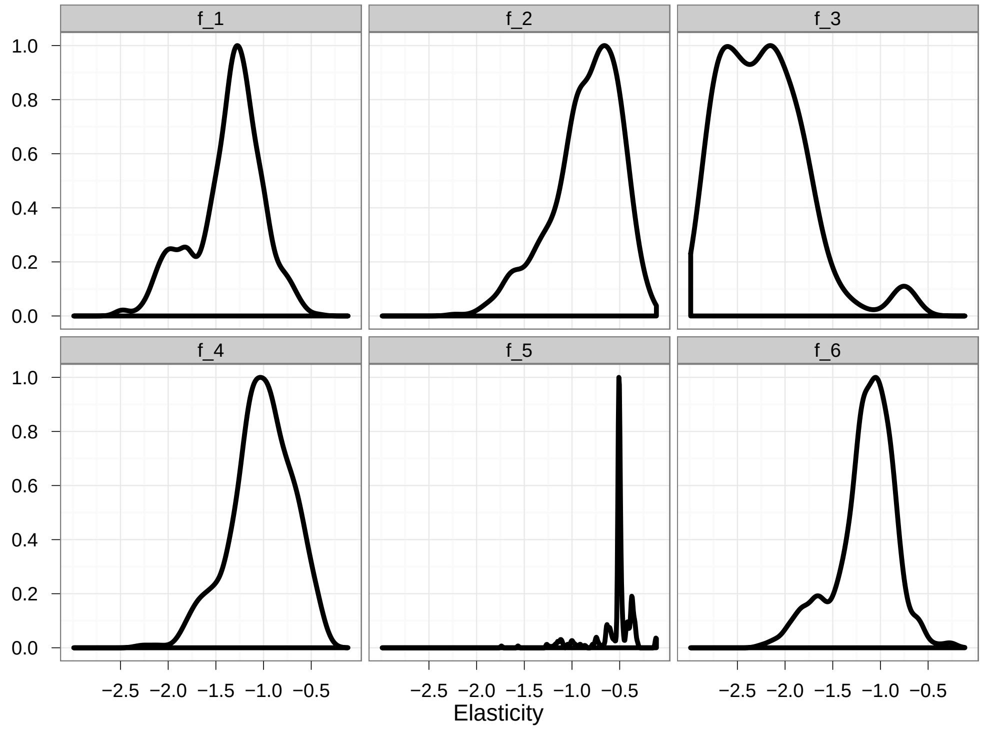

Figure 2: Models by region