CEEPR Center for Energy and Environmental Policy Research

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05-001 WP February 2005

A Joint Center of the Department of Economics, Laboratory for Energy and the Environment, and Sloan School of Management

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Abstract

Sharp price fluctuations and increasing environmental and distributional concerns, among other issues, have led to a renewed academic interest in energy demand. In this paper we estimate, for the first time in Spain, an energy demand system with household microdata. In doing so, we tackle several econometric and data problems that are generally recognized to bias parameter estimates. This is obviously relevant, as obtaining correct price and income responses is essential if they may be used for assessing the economic consequences of hypothetical or real changes. With this objective, we combine data sources for a long time period and choose a demand system with flexible income and price responses. We also estimate the model in different sub-samples to capture varying responses to energy price changes by households living in rural, intermediate and urban areas. This constitutes a first attempt in the literature and it proved to be a very successful choice.

We have benefited from comments by Martin Browning. Financial support from the Spanish Ministry for Science and Education and ERDF (Projects BEC2002-04394-C02-02 and SEC2002-03095), and the Galician government (Project PGIDIT03PXIC30008PN) is also acknowledged. The authors remain solely responsible for any errors or omissions.

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1. Introduction

The self-evident importance of energy in contemporary developed societies and economies constitutes a first reason for deep academic analysis in the field. There are also other issues and facts, most of them quite recent, which reinforce research needs and interests. Indeed, growing price fluctuations of primary energy goods, increasing shares in public receipts from energy taxes, correction of rising environmentally-related damages, or the widespread application of de-regulatory packages have all led to significant economic effects through energy price changes.

Either due to oscillations in primary sources or to the application of public policies, energy price modifications have sizeable consequences on welfare. Both efficiency and distributional questions must be addressed to provide a complete evaluation of price shocks, which could be used to define compensatory measures or for policy design and reform. Obviously, such a comprehensive assessment requires a full and detailed understanding of energy demand. This is the context for the paper where, for the first time, a household energy demand system is estimated for Spain.

Spanish households are important contributors to total energy demand, representing approximately 30% of final consumption as in other developed countries. Yet household consumption shares lie between 20% and 35% in the most important energy goods, raising differences even with EU neighbours because of variable energy endowments, climate and institutional settings. Among those Spanish specifics, the lax application of tax, savings and environmental policies on the energy domain has resulted in a fast growth of total and household energy demand since the 1980s. In a context of extreme dependence on foreign energy stocks, energy efficiency and environmental indicators have so far shown a very poor performance in Spain. Therefore, intensive public policies and significant price effects on energy goods are expected in the short term, which clearly vindicates our approximation to the issue.

There is an extensive empirical literature on household energy demand estimation (see Madlener, 1996). Most papers use microdata and econometric single equation models for household demand of electricity, gas and car fuels. They estimate residential demand conditional on prices, durable goods (heating system, stock of electric appliances, cooking technology, etc), housing (size, house vintage, insulation, etc) and household characteristics (number of members, age, income, etc)[1]. Some models adjust the demand of energy in physical units instead of expenditure, as Nesbakken (2001), who simultaneously estimates a discrete and a continuous model of energy consumption for space heating in Norway[2]. Other recent studies specifically focus on demand for car fuels, given its significance in residential consumption baskets and the strong price variations (Schmalensee and Stoker, 1999; Puller and Greening, 1999; Yatchew and No, 2001; and Oladosu, 2003).

A major inconvenience of single equation models is their imposition of implausible separability restrictions, thus being unable to estimate cross-price effects between different energy goods. One exception is Baker *et al.* (1989), who use a quadratic model to estimate gas and electricity expenditure in the UK, including several energy prices as regressors in each single equation. However, relatively little attention has been devoted to the estimation of household energy demand through multiple equation modelling. Baker *et al.* (1990) estimate a demand model for eleven goods in the UK that incorporates household energy, car fuels and public transport. A similar approach is found in Labandeira and Labeaga (1999) where, in addition to other four non-durable goods, a quadratic household demand model for Spain includes electricity, gas, car fuels and public transport. Also using a quadratic model, Nicol (2003) estimates the demand for car fuels, public transport, and four other goods for Canada and the USA.

In this paper we estimate a demand model especially designed for a simultaneous analysis of energy goods, dealing with the main issues arising in the estimation of complete equation systems. Our ultimate objective is to provide reliable income and price responses, useful for the economic assessment of real or hypothetical changes. Therefore we first combine data sources for a long time period to have enough price variation, using microdata from standard and rather detailed cross-section Spanish household expenditure surveys between 1973 and 1995. We also

[1] Leth-Petersen (2002) is a recent example of this approach, although it does not include energy prices as explanatory variables.
[2] These sophisticated models were pionered by Dubin and McFadden (1984), who estimated both the choice of heating technology (discrete choice) and energy consumption (continuous choice).

choose a demand system, the quadratic extension to the Almost Ideal Model of Deaton and Muellbauer (1980), with a solid theoretical foundation and able to yield a realistic picture of the substitution, own price and income effects.

We explore in the article, through the most disaggregated energy demand model estimated so far in the scientific literature, consumer choices in electricity, natural gas, liquefied petroleum gases (LPG), and car fuels for private transport. The demand system also incorporates public transport, food and other non-durable goods, given their relevance in household consumption. Explanatory variables include those found as significative by the literature on the issue as place of residence, household size, age, education or labour force participation. This way, we can control for observed heterogeneity in the energy profiles of different households.

A noteworthy contribution of the paper is the estimation of the model with different sub-samples to capture varying responses to energy price changes by households living in rural, intermediate and urban areas. This is quite relevant because many households do not have the possibility of accessing some energy goods and thus to substitute away when prices change. We found this approach very successful in empirical terms, representing a first development in this direction within such a disaggregated energy demand system.

Despite the above mentioned relevance and problems associated to Spanish household energy demand, the existing literature on this issue is scarce and incomplete. One of the few exceptions, Labandeira and Labeaga (1999), has been considerably improved by the inclusion of new explanatory variables and by the use of a much longer time period through a combination of different data sources that improves the identification of price effects. We have also pursued a more genuine energy demand system by reducing the number of non-energy goods and disaggregating natural gas and LPG from the previous gas group. This is highly recommendable because gas household consumption patterns are completely different attending to income levels and places of residence.

We report several interesting results in our exercise. On one hand, a significant relationship was found between spending on different energy goods and place of residence, household composition and head status. On the other hand, all but one of the demand equations require quadratic expenditure terms, probably due to the presence of substantial heterogeneity. Moreover, we find easier to fail to reject the theoretical assumptions in homogeneous rather than in heterogeneous models. These two facts point towards misspecification of linear demand models (the need for a complete profile of observed heterogeneity) or misspecification of unobserved heterogeneity, potentially correlated with observables.

Concerning price elasticities, we show that energy products are rather inelastic in Spain. Electricity is the most elastic good, in contrast to the price independence of natural gas. If we move to income elasticities, food, electricity and LPG are normal goods, natural gas, car fuels and public transport are luxuries, whereas LPG are the most income inelastic energy source. Income and price elasticities vary with different types of households grouped by their place of residence, which has important efficiency and distributional implications because some households have limited possibilities to substitute energy goods. Of course, all these results have important implications for the reform or design of future Spanish energy and environmental policies.

The paper is structured in five sections, including this introduction. Section 2 presents the general theoretical framework for our demand analysis. The following section deals with data, empirical specification and methods used in our estimation. The results (parameters and elasticities) are shown in Section 4, based both on estimations with whole sample and with sub-samples by household location. Finally, we conclude the paper with a summary of the main findings and some derived policy implications.

2. Two important choices in estimating demand models

There are several relevant matters when adjusting demands. A fundamental reason for concern is the use of the estimated parameters with purposes of prediction, welfare evaluation or revenue simulation of policy packages. That is why empirical models intend to provide adequate price and total expenditure responses, which request two primary and important decisions on: *i)* the use of a suitable data set and *ii)* the choice of a sufficiently flexible demand system.

2.1. The data

Concerning the choice of the data, one ideally would like to have panel data for long time periods, but this is not common. Instead, it is more usual to have aggregated data, repeated cross-sections or short-time panel databases. In all but aggregated data surveys, income, price and demographic characteristics are reported but with the usual problem of having short-time series for prices. This generates the potential for under-identification of price effects, which is normally worsened by price aggregation due to the inexistence of regional or other type of potential variation[3]. Even when panel data is available for rather long periods, multicollinearity among price series does not allow to have precise estimates of own or cross price effects for most goods (Labeaga and López, 1997). As an illustration, Figure 1 reports the evolution of prices in the Spanish Continuous Family Expenditure Survey (ECPF), a panel database, between the third quarter of 1985 (853) and the fourth quarter of 1995 (954).

(Figure 1, here)

In the case of demand system estimation from aggregated data, the problems are well known (see e.g. Deaton and Muellbauer, 1980 or Blundell *et al.*, 1993). When microeconomic data are available for a long time period, however, there is no difficulty in obtaining efficient price responses even when adjusting the model on pooled data or on pseudo panels (Baker *et al.*, 1990 or Baker and Pashardes, 1991). When the problem consists of insufficient or common variation in the dynamic behaviour of price series, several alternatives have been proposed. Labeaga and López (1994) combine different surveys, Nichèle and Robin (1995) simultaneously use aggregated and micro data, Blundell and Robin (2000) and Labeaga and Puig (2004) estimate a latent separable demand system instead of a weakly separable one. In this sense, Labeaga and López (1994) get enough variation to mitigate collinearity, whereas Nichèle and Robin (1995) obtain price parameters from

[3] Prices can also be measured with errors as in Nicol (2001), although the discussion about the implications of this problem lies beyond the scope of this paper.

aggregate equations estimated on long-time series and then they estimate household demands after substituting the first-step price coefficients. Finally, latent separability permits grouping goods and reducing the dimension of the price matrix, which alleviates multicollinearity problems.

In this paper we opt for combining microdata for a sufficiently long time period. Proceeding this way we are able to obtain long-run and significative responses to price changes, which is especially important when the final objective is simulating policy impacts. We combine data for two waves of the Spanish Family Expenditure Survey (EPF), 1973-74 and 1980-81, and forty waves of the Continuous Family Expenditure Survey (ECPF) for the period 1985-1995. EPF are typical cross-sections involving more than 20,000 households and covering a period of four quarters, from the second quarter of the first year to the first quarter of the second year. The ECPF is a rotating panel based on a comprehensive survey that involves interviewing 3,200 households every quarter. Both surveys are run by the Spanish National Institute of Statistics (INE).

2.2. The demand system

There has been recently a renewed interest in estimating demand models for several reasons. Firstly, usual demand models (up to rank two) have resulted either in rejecting the theoretical assumptions or have provided elasticity figures not rich enough to represent all the heterogeneity in consumer behaviour. Thus, many applications use demand systems with at least rank three (Banks *et al.*, 1997; Lissyotou *et al.*, 1999 or Nicol, 2001) or even rank four (Lewbel, 2003). Secondly, there are several relevant theoretical and empirical aspects of demand models which should be taken into account in the empirical applications: *i)* the importance of observed (Blundell *et al.*, 1993) and unobserved heterogeneity (Labeaga *et al.*, 2001), and *ii)* the treatment of endogeneity (or separability) of some variables as labour supply (Browning and Meghir, 1991) or total expenditure (Keen, 1986; Hausman *et al.*, 1995). Finally, as stated in the introduction, the relevance of the energy domain in contemporary societies and the volatility of energy prices have fostered an intense attention to energy demand. This is the setting for the remaining of the paper, where we focus on several of the previous issues when estimating a complete energy demand model.

It should be first clear that energy products can be considered as intermediate consumer goods needed to yield some final household goods and services, so they can be modelled in a production function framework (Baker *et al.*, 1989). As per usual in microeconomic demand system estimation, we assume that consumers follow a two-stage budgeting process. They first decide their leisure, savings and investment (durable goods), distributing total expenditure in a number of non-durable commodities in the second stage. In this sense, we proceed with the usual separability assumptions.

Our choice is the quadratic extension of Deaton and Muellbauer (1980) Almost Ideal Demand Model, as proposed by Banks *et al.* (1997). This demand system allows for flexible income and price responses and it does not have constant elasticities, as they depend on the level of expenditure. In this sense, Nicol (2001, 2003) reveals the interest of rank-three models in demand systems using data from the US CEX or the Canadian FAMEX consumer expenditure surveys. Pashardes (1995) also shows the relevance of these models for the identification of equivalence scales. The option we chose enriches the demand model and leaves less space for miss-specification.

To define the model, we start by a within-period indirect utility function that reflects the need for quadratic Engel curves

$$v_{ht}(x_{ht}, \mathbf{p}_{ht}) = \left[b_{ht} / \ln(x_{ht}/a_{ht}) + d_{ht} \right]^{-1} \tag{1}$$

where $a_{ht} = a(\mathbf{p}_{ht})$ is a linear homogeneous price index, and $b_{ht} = b(\mathbf{p}_{ht})$ and $d_{ht} = d(\mathbf{p}_{ht})$ are zero homogeneous in prices. We derive the demand equations for goods $i, j = 1, 2, \ldots I$, by taking the Almost Ideal parameterisation of Deaton and Muellbauer (1980) for a_{ht} and b_{ht}

$$\ln a_{ht} = \alpha_0 + \sum_{j=1}^{I} \alpha_j \ln p_{jt} + \frac{1}{2}\sum_{j=1}^{I}\sum_{i=1}^{I}\gamma_{ij} \ln p_{it} \ln p_{jt} \tag{2}$$

$$\ln b_{ht} = \sum_{j=1}^{I} \beta_j \ln p_{jt} \tag{3}$$

and we define d_{ht} as in Banks *et al.* (1997)

$$d_{ht} = \sum_{j=1}^{I} d_j \ln p_{jt} \tag{4}$$

Applying Roy's identity we have the budget shares

$$w_{iht} = \alpha_i + \sum_{j=1}^{I} \gamma_{ij} \ln p_{jt} + \beta_i \ \ln\left(x_{ht}/a_{ht}\right) + \frac{\lambda_i}{b_{ht}}\left(\ln\left(x_{ht}/a_{ht}\right)\right)^2 + u_{iht} \tag{5}$$

where w_{iht} is the participation of good i in total expenditure by household h at moment t. The price vector faced by households at each moment in time is $\vec{p}_t = \left(p_{1t},....,p_{It}\right)$, whereas x_{ht} is total expenditure. Since we have several observed demographics, z_{ht}, the model is flexible enough to allow functions of the parameters in (5) to affect demand. They shift both the intercept and the slopes of the share equations, so we can express

$$\alpha_i = \alpha_i(z_{ht}),\ \beta_i = \beta_i(z_{ht}) \text{ and } \lambda_i = \lambda_i(z_{ht}) \tag{6}$$

Differentiation of equation (5) with respect to total expenditure provide the following income elasticitiy for each good i and household h,

$$e_i^h = 1 + \frac{\mu_i^h}{w_i^h} \tag{7}$$

where

$$\mu_i^h = \beta_i + \left(2\lambda_i \ln \frac{x_h}{a(p)}\right)\frac{1}{b(p)} \quad (8)$$

Goods that exhibit income elasticity larger (lower) than one are luxuries (necessities). However, (8) implies that each good can be either a necessity or a luxury for different households, depending upon the distribution of total expenditure. The uncompensated elasticity of good *i* with respect to the price of good *j* for household *h* is again obtained by differentiating equation (5) with respect to the price of good *j*,

$$e_{ij}^{uh} = \frac{\mu_{ij}^h}{w_i^h} - \delta_{ij} \quad (9)$$

where

$$\mu_{ij}^h = \gamma_{ij} - \mu_i^h\left[\alpha_j + \sum_{k=1}^{N}\gamma_{jk}\ln p_k\right] - \left[\beta_j\lambda_i\left(\frac{\ln x_h}{a(p)}\right)^2\right]\frac{1}{b(p)} \quad (10)$$

δ_{ij} is the Kronecker delta equal to 1 if i=j and zero otherwise. We can use the Slutsky conditions to derive the compensated price elasticities,

$$e_{ij}^{ch} = e_{ij}^{uh} + e_i^h w_j^h \quad (11)$$

3. Data, empirical specification and methods

3.1. A first look at the data

To estimate the model we only use energy expenditure referring to the first home, thus avoiding distortions due to contract overheads in second homes. Furthermore we exclude all households that report null expenditure on food and electricity, and those with income, total expenditure and expenditure on each good below 2% and over 98% of the distribution to rule out outliers[5]. Table A1, in the Appendix, presents some descriptive statistics of variables in the database before and after selection.

The demand model contains the following aggregation of goods: electricity, natural gas, LPG (butane and propane gases), car fuels, public transport, food and non-alcoholic drinks, and other non-durable goods. In the case of aggregated goods, price is the weighted sum of the original price indexes as published by INE. We have used expenditure figures in the year 1992, the base year for the ECPF, to estimate the weight of each individual good in the corresponding aggregate good in the model.

Figure 2 summarizes the changes on the share of each good on total expenditure between 1973 and 1995. During this period there were important modifications on the structure of Spanish household consumption on the preceding goods. The share of natural gas grew by 159% because of the increasing number of households connected to the grid. At the same time, there was a rise on the share of electricity by 41%, due to a larger number of electric appliances held by households, and a simultaneous 40% decrease in the share of LPG in total expenditure. This means that there certainly was an important substitution process between 1973 and 1995 in residential energy consumption, with a large number of households switching LPG for electricity and natural gas.

(Figure 2, here)

Figure 2 also shows a significant substitution of private for public transport during those years. The share of car fuels on total expenditure rose by 63%, whereas the share of public transport went down by 31% as a result of the increasing number of vehicles in Spain[6]. It is interesting to note that, unlike in other consumption categories, there are remarkable discontinuities in the observed expenditure trends on car fuels and public transport that are related to the effects of oil crises during those years. Finally, the figure also depicts a sizeable decline in the

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[5] To control for infrequency purchase problems in natural gas, LPG and car fuels, the 98% rule was applied to those households that reported positive expenditure.
[6] Between 1975 and 1995 the number of inhabitants per vehicle decreased in 75%, from 11 to 2.76 (Universidad Politécnica de Madrid, 2000).

expenditure on food and non-alcoholic drinks and a simultaneous rise in other non-durable goods between 1973 and 1995, as expected from the large rise in wealth of Spanish households during these years.

The most common combination of energy goods in 1995 is electricity and LPG, consumed by 70.5% of Spanish households, followed by simultaneous consumption of electricity and natural gas (13.4% of households). The consumption of solid, liquid heating fuels and collective central heating do not show, as expected, significant values. The place of residence is clearly an important variable to explain energy consumption by the household, mainly due to availability of connections and housing type. Therefore, the location of the household affects either directly or indirectly to the consumption of energy goods for the house[7].

Different consumption patterns of energy goods among households are not only caused by location in rural or urban areas, as can be observed from the calculation of the Gini index for total expenditure and of the concentration indexes for expenditure on each good. Indeed, we found significant differences in concentration indexes for expenditures in several energy goods and public transport between households living in municipalities with more than 50,000 and also with less than 10,001 inhabitants (Labandeira *et al.*, 2004*a*).

As indicated later on, the empirical application of the demand model must solve some problems such as the existence of measurement errors for some goods, which also affects total expenditure. To analyze this problem we use the ECPF 1985-1995 in its panel form, which allows us to follow the same household over a maximum of eight consecutive quarters. Table 1 reports the percentage of null expenditures for those households that have at least one positive record and collaborated for more than three quarters. For example, fuels for heating purposes such as oil, coal or wood are typically bought twice a year[8], and the number of null expenditure records is around 55% for both solid and liquid fuels in households that report positive expenses. Therefore, this phenomenon may be not related to absence of consumption but to infrequency of purchase and in this case we would have

[7] For a further description of theses issues see Labandeira *et al.* (2004*a*).
[8] The same problem is reported in Baker *et al.* (1989).

wrongly measured household consumption during the different quarters of the sample.

(Table 1, here)

There are also some problems with observed expenditure on collective central heating. It was usual in the past that households sharing collective central heating means spread the total cost on a per capita basis and so expenditure on this good is not directly related to individual household consumption but rather to the average for some households. Thus in presence of high infrequency or collective consumption there would be important measurement errors, as the expected values of expenditure and consumption are the same but expenditure measures consumption with error. Positive expenditures overstate consumption and zero expenses do the opposite as, for instance, energy purchases in autumn may be consumed during winter. That is why we decided not to estimate the demand for these goods separately, aggregating them to other non-durable goods[9].

3.2. Empirical specification

We are interested in estimating equation (5), allowing for heterogeneity in intercepts and slopes in the form defined by equation (6). Therefore, dependent variables are shares of expenditure on each of the seven non-durable goods and we include a range of explanatory variables. However, both the definition of the variables used and the inclusion of some determinants of demand are restricted by the combination of different surveys. This requires some additional explanations.

As indicated before, we take data from three surveys: two standard cross-sections for 1973-74 and 1980-81 (EPF), and cross-sectional time-series data from 1985-95 (ECPF)[10]. EPF is a very comprehensive microdata survey on household expenditure, income and characteristics, including information from approximately

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[9] Infrequency problems in expenditure reported by households for the considered aggregated goods are, however, of little importance because we use annual data for estimation.

[10] We first attempted to estimate the model with quarterly data from the ECPF 1985-95. Unfortunately, there were few changes on most energy prices, which also varied collinearly during that time span. Therefore, we were unable to correctly identify price effects.

24,000 households with 170 different goods during 1973-74 and 632 goods in 1980-81. Expenditure on these goods by each household is reported for a natural year, in some cases estimated by INE as information is collected on a weekly basis[11]. On the other hand, the ECPF 1985-95 is a rotating panel based on a comprehensive survey with 252 different goods and quarterly data for 3,200 households.

It was imperative to achieve compatibility between data from those surveys, although there were some differences in the classification of goods and in households' characteristics. To overcome those problems we aggregated expenditures in homogeneous goods following survey definitions, and used the same methodology for demographics by defining new variables containing the same household characteristics in the three surveys. Additionally we had to estimate annual expenditures for each household in the ECPF to make it compatible with EPF. In calculating annual expenditure data for 1985-95 we only used households that collaborated during the four quarters of a year.

Neither EPF nor ECPF provide information on prices, however, and so they were obtained from INE in the form of indexes on a monthly basis[12]. We aggregated goods for those indexes so as to make them compatible with our cross-section data and expressed them on base 1992. For the years 1973-74 we used as a proxy the price index for January 1976, since the INE did not provide prices for most goods in the model. For the 1980 EPF we used prices referring to the quarter in which each household was interviewed in, although data refer to individual annual expenditure. Finally, we adjusted the annual price index for each good between 1985 and 1995 as an aritmetic mean of quarterly prices.

In addition to prices, the empirical model considers several dummy variables that modify the intercept and intend to capture heterogeneity in the range of energy sources consumed by Spanish households. Moreover, most of these variables are usually significant in the empirical literature (Baker *et al.*, 1989; Blundell *et al.*, 1993, Labandeira and Labeaga, 1999 or Nicol, 2003). More specifically, we include dummies for the educational level of household heads (no education, secondary

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[11] See e.g. Baker *et al.* (1989) for some comments on data collection processes in this type of surveys and their implications.

[12] See the Appendix for some further details on price and tax rate data.

level, higher education), geographical location of the home (rural, village), ownership of the main dwelling, whether the head of the household is retired from work, and the number of household members by age (15 or under, older than 15). Moreover, we use a trend variable to control possible tendencies in any of the expenditure groups or technical progress in domestic appliances or vehicles that consume different energy goods[13]. Most of these variables are also included as interactions of total expenditure.

Household size is an important explanatory variable as consumption of food, public transport and non-durable goods should be a function of the number of household members. The same may apply for car fuel and energy for the house consumption. On the one hand, the number of household members could give some insight about the size of the house: the greater the size, the larger consumption of energy for the house. On the second hand, the number of household members by age is also important for transport services consumption (either public transport or car fuel for private transport): e.g. anyone more than 14 years old can ride moped in Spain, and those over 16 years can ride motorcycles up to 125 cc.

Besides, consumption of energy goods could be related to the age of the head of the household through two ways: preferences may be different because of cultural reasons, and age could provide some insight about the characteristics of the house and the stock of appliances (house vintage, heating system, etc). For instance, Baker *et al.* (1989) and Leth-Petersen (2002) found that house characteristics are important variables in explaining energy expenditures.

Finally, it should be taken into account that energy expenditure is the result of the joint demand of a stock of appliances and their level of usage. The preceding data analysis hinted how to face the empirical exercise without information about the stock of household appliances, which is not provided by the surveys. In their absence, some of the variables included in the empirical model attempted to proxy these effects. For example, higher income households, probably with a better

[13] To avoid perfect collinearity we dropped a variable from each set of dummies, primary schooling in the case of education. Rural corresponds to those households living in municipalities with less than 10,001 inhabitants. Village corresponds to those households living in municipalities with more than 10,000 inhabitants but less than 50,001. We dropped the dummy corresponding to households living

education level, are likely to have more expensive and efficient appliances and better insulated houses. Moreover, the type of durable goods in the house could be subject to heavy restrictions by, for example, the type of tenancy on the property (rental, owned), as it is found by Baker *et al.* (1989) for electricity and gas.

3.3. Econometric methods

The econometric methods we use to estimate the system in equation (5) are guided by an adequate treatment of measurement errors in total expenditure as well as by the imposition of the theoretical restrictions. The presence of dependent variables with measurement errors, makes necessary to use alternative estimation methods to Ordinary Least Squares (OLS). OLS provides inconsistent estimates due to the existence of contemporaneous correlation between the error term and total expenditure. This can be solved by instrumenting total expenditure with total income, which under separability conditions must be uncorrelated with the error term (Keen, 1986). We employ as identifying assumption the exogeneity of prices and demographic characteristics.

We use an instrumental variable (IV) method that requires some clarifications. First, the model is non-linear in parameters and thus we should employ non-linear IV. This is the reason for applying an iterative procedure with starting values taken from a first stage estimation of a linear version of the model. In this sense, we estimate a linear model in a first stage by substituting *a(p)* by a Stone index, $\ln p_{ht} = \sum_{j=1}^{I} w_{jht} \ln p_{jt}$ and assuming that *b(p)* is equal to unity. Once this has been done, we use these initial estimates to obtain the non-linear ones through an iterative method until convergence is achieved (for additional details see Blundell and Robin, 1999).

A second issue refers to identification of α_0 in equation (2). We use as guess estimate for α_0 the value just below the minimum of log of real total expenditure, following the suggestions by Deaton and Muellbauer (1980) and Banks *et al.*

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in municipalities with more than 50,000 inhabitants. Characteristics of the baseline household are

(1997). There are alternatives, however, such as providing a grid of values and choosing the estimate that maximizes some criteria. We can also estimate α_0 jointly with the rest of parameters in the system (2)-(5), as in a simultaneous triangular equation system. In any case, we have tried with several values of α_0 and the results are robust to the chosen alternatives.

Concerning theoretical restrictions, it should be noted that each equation is a linear combination of the others. Therefore, to avoid singularity of the variance-covariance matrix of errors, one of the equations needs to be left out of the estimation. In our case, the demand equation of other non-durable goods is not estimated and its parameters are recovered through the additivity restriction[14]. Moreover, for the estimated demand system to be coherent with consumer theory, we impose symmetry and zero degree homogeneity conditions. The homogeneity restriction is imposed in the model by using prices relative to the good excluded in the estimation. It will be possible to test the homogeneity condition for each of the estimated equations, as well as for the system as a whole[15]. The symmetry condition ($\gamma_{ij} = \gamma_{ji}$) is imposed during estimation, and is tested jointly with homogeneity using a Chi-squared test. Negativity cannot be imposed, but it can be tested looking at the sign of the Slustky matrix.

During estimation we also impose that price indexes in equations (2)-(4) are common across goods. It must be noted that this modeling approach may result in price coefficients and elasticities biased upwards (Micklewright, 1989). Moreover, the structural parameters of the model will not be identified when, for instance, a rise in fuel prices leads to energy savings, substitution and investments in house insulation. However, reduced-form parameters will be appropriate as long as we are interested only in forecasting the effects of changes in market prices and not in the precise mechanism that takes place in each household.

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reported in the Appendix (Table A1).

[14] This condition imposes that $\sum_{i=1}^{I}\alpha_i = 1$, $\sum_{i=1}^{I}\beta_i = 0$, $\sum_{i=1}^{I}\gamma_{ij} = 0$, and $\sum_{i=1}^{I}\lambda_i = 0$.

[15] The homogeneity condition is satisfied if, and only if, $\sum_{i=1}^{I}\gamma_{ij} = 0$.

4. Results and discussion

4.1. Estimates based on the whole sample

In Table 2 we present the most significant results obtained in the estimation of the demand system, leaving their comparison based on elasticity figures for the next section. As expected, home ownership is a relevant factor explaining energy expenditure in Spanish households. Being the home owner significantly reduces expenditure shares of natural gas, car fuels and public transport and increases those of LPG, electricity and food. This resembles the consumption patterns of those households living in rural areas, where home ownership is rather common. We included an interaction term between total expenditure and the dummy for ownership, getting the opposite results than above. This indicates that the weight of necessity expenditures is lower in high income households, as expected, precisely those that can access home ownership under better conditions in financial markets.

(Table 2, here)

The demand for electricity and LPG is negatively related to the educational level of the household head. However, we must note again that a positive relationship at all income levels dominates when including an interaction term between income and the educational dummies. More importantly, the direct effect of education and its indirect effect through income cancel out for electricity and LPG. This implies that the household head education level does not condition the choice of energy source for the home. Finally, once we account for both direct and indirect effects, there is not a significant effect of household head education on the expenditure of natural gas, car fuels, public transport or food.

A significant relationship between spending on different energy goods and place of residence is also found, as expected. Once we take into account both the direct effect plus the interaction term between place of residence and income levels we found that households living in smaller municipalities (less than 10,001 inhabitants) present a higher share of electricity on total expenditure (34% more than the average), the reverse being applicable for LPG (1% less). Furthermore, households living in rural areas reduce their expenditure on food by a 17.5% with respect to the average.

We also obtained that households living in smaller municipalities spend more in car fuels and less in public transport: households living in towns with less than 10,001 inhabitants show a share of car fuels over total expenditure 95% larger than households living in cities with over 50,001 inhabitants, and their expenditure share on public transport is 100% lower. In accordance with the results associated with each of the four municipality types, a progressive substitution of public transport for car fuels is observed as municipality size increases.

Household composition is another very important determinant of energy spending. Each household member with less than 15 years increases the share of expenditure in car fuels by 20% with respect to the average, one of the reasons probably being that they are carried out to school by car, whereas those aged over 15 increase that share by 43%. We obtain an analogous behaviour when referring to the estimates corresponding to public transport, with respective increases of 47% and 220% in the share of spending for the same ages. These results probably respond to the fact that younger members do not consume public transport by their own and that older members can ride a motorcycle or drive a car.

Household composition also affects the expenditure on energy for the house. We found that each member aged over 15 reduces the share of electricity on total expenditure by 32%. On the other hand, each household member below 15 reduces the share of LPG by 20% and those over 15 reduce the share by 50%. This result is counterintuitive and must be related to the indirect positive relationship between income levels and the number of household members. Finally the expenditure on food is negatively affected by the number of members in the house which, in accordance with Engel's law, is also linked to the income level in an indirect way.

Besides, a relationship between retired household head and expenditure on energy goods for the house was observed. In such households the shares of electricity and LPG expenditure are respectively increased by 53.5% and 62%, which could be explained by longer stays at home of senior citizens. Some specific effects are also observed for this group of households regarding food and transport expenditure shares. The former shows a reduction by 22.5%, linked to the preceding higher energy expenditures, whereas households with a retired head spend 46% less in private transport and 77.7% more in public transport services. These changes could be explained by less transport needs and by the existence of low fares for older people that fosters public transport use.

We did not find significative effects of the above variables on the consumption of natural gas. This is probably due to the fact that this type of energy is mainly consumed in big cities and by households with more than average income that conform a rather homogeneous group.

Finally, we observed the need of introducing the quadratic term in the electricity, natural gas, public transport and food equations. However, there is no significative income effect on LPG and the quadratic term is not significative in car fuel consumption. This is to be expected with LPG, as it is mainly consumed by poorer households. The result for car fuels simply indicates that the use of cars and the subsequent fuel consumption is generalized among the Spanish population, independently of their income levels.

4.2. Comparisons of results from the whole sample and from sub-samples by location of the household

As an alternative to parameter estimates, in this section we present the elasticity figures for three sub-samples and a comparison with those obtained when using the whole sample. A major contribution of the paper consists in estimating the model with sub-samples constructed by place of residence of the household. A similar exercise has been carried out for different regions within a country (Blundell *et al.*, 1993; Nicol, 2003), but to our knowledge this is the first ever application that differentiates between types of municipalities. We do this for at least two reasons: *i)* significant differences in consumption of the seven considered goods related to the place of residence have been already shown, and *ii)* household access to several energy goods and public transport is very limited in some cases[16]. Of course, this has important implications for the substitution possibilities among energy goods for the house and between private and public transport.

Elasticities are obtained by using equations (7)-(9) and are evaluated at sample means for all households as well as for those households who consume the good. We can provide a distribution of elasticities too, although to keep tables manageable we focus on the groups with different elasticities at different income values. It should first be noted that the reported figures provide short-run values, as we adjust the decision about distribution of total expenditure within groups in a given period. Nevertheless, the sample covers a time period of 22 years and so the figures can be also interpreted, to some extent, as long-run elasticities.

Panel A in Table 3 reports total expenditure elasticities calculated using the parameter estimates for the whole sample. It can be seen in the first column that food, electricity, natural gas and LPG are defined as normal goods, whereas car fuels and public transport are luxuries. Once we control for positive expenditure on the group (column 2), the size of the values are reduced for luxuries and increased for normal goods, except in food and electricity where all observations have been selected to be positive. The distribution of the income elasticity for electricity shifts from a luxury good for poor households (1.01) to a value of 0.53 for rich households. LPG is the most income inelastic energy source and the distribution of its elasticity is continuously decreasing, being a Giffen good for 25% of richest households, although these negative values are not significatively different from zero. As regards public transport, the values run from a maximum of 1.74 for households in the bottom decile of income to 1.50 for households in the upper decile. In the case of food, figures vary from 0.70 for the poorest decile to 0.33 for the richest one. Natural gas and car fuels maintain roughly the same values across the distribution of total expenditure.

(Table 3, here)

[16] Although regional differentiation of households approximates the varying climatic conditions across a country, it does not necessarily inform on variable access to energy goods and services.

Table 4 shows uncompensated own price elasticities, also evaluated for the whole sample and for different sub-samples[17]. The figures at mean values (columns 1 and 2) reflect that electricity shows the largest uncompensated responses to prices, which should be related to the multiple services provided by this good (lighting, cooking, heating, etc.). On the contrary, demand for natural gas can be considered price independent, probably because it was only introduced in cities during the sample period, with a rather stable price and an increasing share in Spanish household consumption. For these two groups of goods, the Slutsky matrix does not fulfill negativity conditions for 1% of households. Elasticity for LPG is larger than that for natural gas but much lower than that for electricity. This could be explained because the LPG share is extremely small for a large number of households.

(Table 4, here)

There are some differences both in total expenditure as well as own price elasticities when they are computed taking into account the location of the household (panel A, columns 3 to 5). The most remarkable changes are seen in natural gas, more income elastic for urban households and showing zero elasticity for rural households who have no access to this energy source. On the other hand, car fuels are significantly more income elastic for rural households. However, public transport presents very similar income elasticity values, which has to be related to the low use of public transport by Spanish households (mainly at median and high income values) irrespective of the place of residence.

Regarding own price uncompensated elasticities, natural gas is more price elastic for urban households, as the rest of households had no access to it during most of the sample period. Actually, Table 4 shows that price elasticities for natural gas and LPG are almost identical for those households who are connected to the grid and therefore can choose between both energies, which reinforces our conclusions (panel A, column 5).

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[17] Compensated elasticities are easy to calculate through equation (11). Given total expenditure elasticities and shares, compensated elasticities are slightly lower than their corresponding uncompensated figures. We do not provide these results, but they are available from the authors on request.

On the other hand, rural and urban household hardly react to changes in the price of car fuels because, in many cases, they cannot substitute away private for public transport. Yet the elasticity of car fuels for urban households almost double that for the whole sample, while elasticity of public transport is almost triple. Electricity roughly shows the same figure for all sub-samples, which means all households use this energy for the same purposes irrespectively of the place of residence. Finally, food is more price elastic for urban households, which is related to higher income levels.

Given the differences detected in the values of the elasticities for some energy goods for the house, car fuels and public transport among households located at different areas, we re-estimate the model in three sub-samples: rural households, households living in towns, and urban households. Although interactions of dummy variables and total expenditure included in the estimation of the whole sample give us more flexibility in income responses, the re-estimation looks for more price flexibility. In panel B of Tables 3 and 4 we report total expenditure and own price elasticities for those sub-samples, showing how income and price elasticities vary when considering different sub-samples. This is quite relevant, as it vindicates the need of introducing observed heterogeneity in the demand models (see Blundell *et al.*, 1993 or Nicol, 2003). Moreover, these differences also underlay the need of considering unobserved heterogeneity, which we could not take into account because of the need for combining different databases. This issue is, of course, in our future research agenda.

The most striking differences between panels A and B of Tables 3 and 4 are seen in natural gas and public transport. These results should be expected, as households living in rural areas have important difficulties to consume those goods. As a consequence, estimation with the whole sample (which results in mean value adjusted regressions) masks the true parameters for sub-samples of population that exhibit different behaviours. For instance, it is well known that natural gas is a luxury good, which is corroborated by panel B but denied by panel A. Furthermore, some anomalies are found in the own price elasticity of public transport in panel A, which are corrected in panel B because rural households are less dependent on this type of consumption.

Although we do not report all cross-price elasticities due to lack of space, some information is provided on the main and most interesting results. Electricity and natural gas are found to be substitutes in urban areas with a small value of the cross-price elasticity (0.04). Moreover, LPG are a substitute for natural and electricity in all areas. Rural households cannot substitute car fuels for public transport, as showed by a cross-price elasticity significantly equal to zero. Finally, given the already mentioned importance of food in Spanish household demand, this group appears to be a substitute for the rest of consumption categories.

Concerning the theoretical restrictions, we provide an example of the importance of estimating demand models in homogeneous samples or properly controlling observed and unobserved heterogeneity. Although we reject symmetry and jointly symmetry and homogeneity, the value of the test varies from 316.40 in the whole sample to 80.48 in the subsample of households living in towns between 10,000 and 50,000 inhabitants. These tests have to be compared with a χ^2 with 21 degrees of freedom.

5. Conclusions

In this paper we have estimated a seven-equation demand system that includes six energy-related products for Spain. Our contribution to the scientific literature is threefold as: *i)* it constitutes the most disaggregated empirical application in terms of energy goods so far; *ii)* an in-depth analysis of the role of household location in rural vs. urban areas is performed, for the first time in the literature, and *iii)* it is the first household energy demand system estimated for Spain.

Before estimation, we took several important decisions to have reliable price and income responses for Spanish households. We first chose the data on which to estimate the model by combining several surveys for a long time period, thus allowing for more price variation and less multicollinearity problems. Secondly, we proposed a rank-three demand model based on state-of-the-art empirical methods and evidence. Thirdly, as the database combination did not allow us to use the panel structure of our data (ECPF) and to minimize the presence of heterogeneity on price and income elasticities, we selected several sub-samples by a crucial variable for the demand of energy goods: household location in rural, intermediate and urban regions.

Our estimation strategy provided several findings. On one hand, all but one the demand equations required quadratic expenditure terms demonstrating its importance as heterogeneity increases. On the other hand, we found that it is easier to fail to reject the theoretical assumptions in more homogeneous models (pooled sample), pointing out to misspecification of linear demand models (the need for a complete profile of observed heterogeneity) or misspecification of unobserved heterogeneity potentially correlated with observables. The results also showed the relevance of including explanatory variables capable to take heterogeneity into account. In particular, a significant relationship was found between spending on different energy goods and place of residence, household composition and head work status (active or retired). As rural, intermediate and urban households do not face the same opportunities to consume energy goods and transport services, when the population size of the municipality increased we reported a progressive substitution of public transport and natural gas for respectively car fuels and LPG.

Concerning own price elasticities, we found that energy products are rather inelastic in Spain, with electricity as the most elastic energy good and natural gas as price independent. Cross price effects exist in some cases, indicating limited substitution between electricity and natural gas in urban areas and LPG and electricity in all locations. When referring to income elasticities, food, electricity and LPG are normal goods, natural gas, car fuels and public transport are luxuries, whereas LPG are the most income inelastic energy sources. Poorer households are more responsive to changes on energy prices, which is obviously related to a larger share of energy on total expenditure. Again, we observed significant differences in some goods related to the place of residence that have important efficiency and distributional consequences.

Policy implications are rather straightforward and directly connected with many of the issues currently faced by Spanish regulators. In fact, the unavoidable policies to reduce an increasing dependence on foreign stocks and growing environmental problems associated to energy consumption could be partially informed by our results. This is the approach followed by Labandeira *et al.* (2004*a*) to calculate the effects of a substantial energy tax-induced price rise through a microsimulation procedure based in our estimates.

As our reported price elasticities indicate only a limited short-term effectiveness of pricing policies to restrict Spanish energy household consumption, other regulatory approaches should be contemplated too. Only electricity consumption seems to be fairly price sensible, which is simultaneous to more than seven consecutive years of falling real prices in Spain due to the sector's liberalization. Given that electricity generators are also dependent on energy imports and cause a myriad of serious environmental problems, that price evolution is probably undesirable. This is even clearer in Labandeira et al. (2004*b*) who integrate a microeconomic model, also constructed with information from this estimation, and a macroeconomic model that incorporates the supply responses from higher energy inputs, concluding that control policies on this sector are cost-effective and thus recommendable.

On the contrary, car fuel demand was found to be particularly price inelastic and this conforms a formidable challenge for public regulators due to the uncontrolled and unsustainable pattern of consumption rises seen in the last decades. It is nevertheless true that price policies may be effective in the medium and long terms, as the preferential tax treatment of diesel has led to a remarkably declining Spanish share of petrol fuelled cars in less than fifteen years. This raises two relevant questions when using prices with corrective purposes: *i)* the need for specific compensation packages to rural households, as stated in our results, and *ii)* the need to explicitly include durable goods linked to non-durable energy modelling. Since the new Spanish household survey (ECPF-98) provides detailed information on the latter, that interesting and rather unexplored issue demands intensive research attention.

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APPENDIX

- **Price and tax rate data**

Data referring to prices available on the INE web site (www.ine.es) in the form of indexes, do not offer enough degree of disaggregation for the objectives of this research. For this reason, we have resorted to various sources to obtain prices for energy goods. Firstly, the International Energy Agency (IEA) regularly publishes *Energy Prices and Taxes*, with current prices and taxes for electricity, heating oil, and natural gas (see, for example, IEA, 2003). Secondly, the Spanish Ministry of Economy has supplied us with current prices and taxes for natural gas and LPG. Finally, the *Enciclopedia 2001* (Oilgas, 2002) provides the prices of various energy goods since the 1970s, with a considerable degree of disaggregation.

The Oilgas 2001 Encyclopedia has been used to obtain price indices for LPG and natural gas, whereas the electrical energy price index has been obtained from *Energy Prices and Taxes*. For the other goods considered in the model, we have used data obtained from the INE.

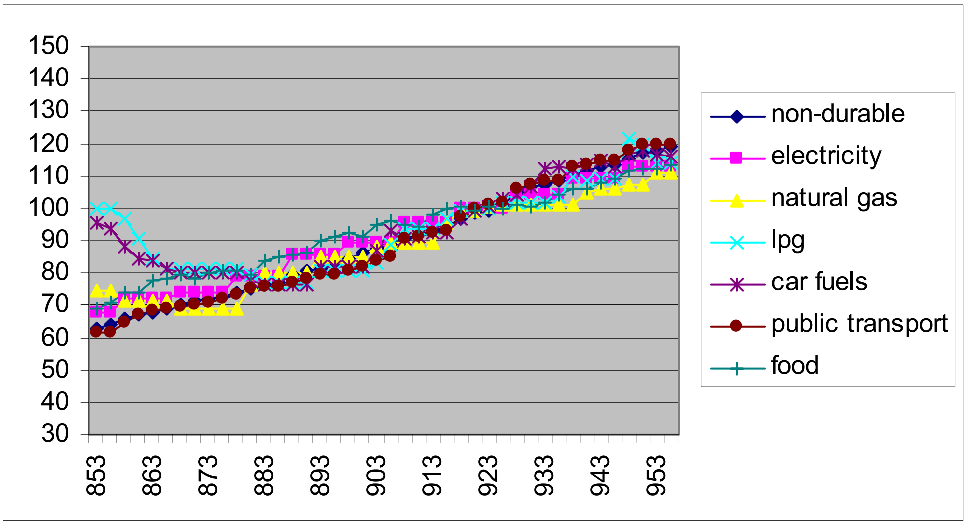
VAT rates born by the various goods groups have been calculated by weighting the corresponding legal rates to each type of expenditure by their relative weight within each group. For the excise duties born by transport fuel, the same procedure has been followed, using data published by the Spanish Tax Agency (AEAT) as source.

- **Descriptive statistics**

(Table A1, here)

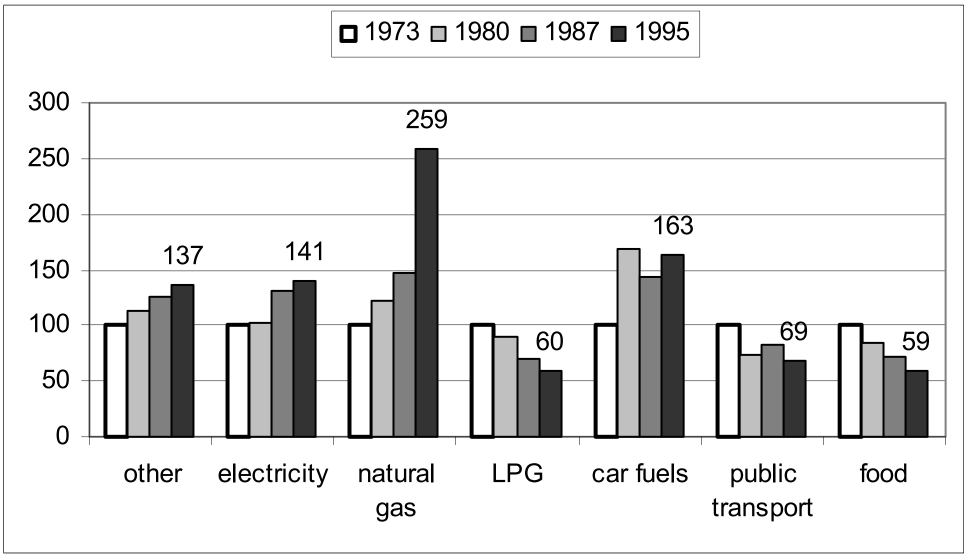
FIGURES AND TABLES

Figure 1. Price indexes for different goods between 1985 and 1995



Source: Own calculations.
Notes: ***i)*** Average price in 1992 represents the base year (100) for the calculation of price indexes for each good. ***ii)*** 853 refers to the third quarter of 1985 and so on.

Figure 2. Changes on share expenditure between 1973 and 1995



Source: Own calculations.
Note: The *y* axis corresponds to mean values of share expenditurees for the whole sample of households. We report index numbers taking 1973 as base year (1973=100).

Table 1. Infrequency (%) on energy expenditure from households that report some positive spell in ECPF 1985-95

Number of quarters / *Goods*	**4**	**5**	**6**	**7**	**8**
Electricity	1.50	1.72	1.54	1.26	1.44
Natural gas	7.96	9.50	10.63	9.86	9.30
LPG	9.91	10.12	11.11	10.47	10.10
Liquid Fuels	53.46	53.41	54.50	57.82	59.30
Solid Fuels	50.00	57.35	62.10	52.71	59.12
Collective Central Heating	10.77	15.09	13.75	11.99	11.66
Car fuels	14.72	15.26	17.08	18.89	17.29

Source: Own calculations.
Note: We define infrequency as the ratio between the number of quarters with positive expenditure and the number of quarters with household collaboration.

Table 2. Parameter estimates from the pooled sample

Goods / *Exp. Variables*	Electricity	Natural Gas	LPG	Car fuels	Public transport	Food
Constant	-0.00679907 (-2.842)	0.00638831 (4.794)	0.00120294 (0.466)	0.00217847 (0.203)	0.0117905 (2.177)	0.42369106 (16.596)
No younger than 15 years	0.00607296 (7.648)	-0.0008078 (-2.303)	0.00946184 (13.494)	-0.01457682 (-4.156)	-0.00197763 (-1.143)	0.14947537 (16.213)
No older than 15 years	0.01396095 (11.474)	-0.00053553 (-0.911)	0.01632321 (14.579)	-0.03987269 (-7.363)	-0.00764345 (-2.861)	0.36759676 (27.046)
Home owner	0.01383189 (6.905)	-0.00336571 (-3.699)	0.01949354 (10.887)	-0.03083811 (-3.478)	-0.00923159 (-2.110)	0.18029051 (7.831)
Primary school	0.01170282 (7.209)	-0.00038013 (-0.556)	0.01365411 (9.709)	-0.01695116 (-2.3709	-0.01253901 (-3.549)	0.05673111 (2.958)
High school	0.03366043 (9.872)	-0.00082653 (-0.573)	0.00782255 (2.649)	0.0576108 (3.844)	0.00164583 (0.222)	-0.02380113 (-0.592)
Rural (<10,001 Inhabitants)	-0.02202445 (-12.887)	0.00156739 (2.140)	0.0058208 (3.901)	-0.05492898 (-7.287)	0.00954801 (2.562)	0.27164365 (13.518)
Village (10,000<inh<50,001)	-0.00427418 (-2.243)	0.00025596 (0.318)	0.00864404 (5.232)	-0.02409107 (-2.870)	-0.00189947 (-0.458)	0.21179184 (9.418)
Principal retired work	0.02392862 (11.345)	0.00033788 (0.347)	0.02845071 (14.949)	-0.01328535 (-1.419)	-0.02387928 (-5.166)	0.30057538 (12.442)
Trend	0.00052735 (8.295)	-8.5972E-05 (-2.619)	-0.00010679 (-1.625)	-0.00046028 (-1.6359	6.5988E-05 (0.464)	-0.00727923 (-10.359)
Younger than 15 * expenditure	-0.00061135 (-7.516)	7.0881E-05 (1.967)	-0.00094232 (-13.102)	0.00149906 (4.1719	7.4203E-05 (0.419)	-0.01346714 (-14.270)
Older than 14 * expenditure	-0.0014332 (-11.565)	3.8353E-05 (0.639)	-0.00161309 (-14.134)	0.00387102 (7.0189	0.000988 (3.630)	-0.03486612 (-25.202)
Home owner * expenditure	-0.00150961 (-7.277)	0.00032784 (3.474)	-0.00209764 (-11.305)	0.00297008 (3.2349	0.00072272 (1.595)	-0.0202541 (-8.499)
Primary sch. * expenditure	-0.00138791 (-8.223)	8.7969E-06 (0.124)	-0.00134538 (-9.213)	0.00152317 (2.049)	0.00132104 (3.598)	-0.00448671 (-2.248)
High school * expenditure	-0.0033348 (-9.756)	0.00010475 (0.724)	-0.00086871 (-2.932)	-0.00542547 (-3.611)	-0.00020149 (-0.272)	0.00035821 (0.089)
Rural * expenditure	0.00205642 (11.675)	-0.00027596 (-3.662)	-0.00055947 (-3.641)	0.00614354 (7.909)	-0.0016118 (-4.197)	-0.02516069 (-12.143)
Village * expenditure	0.00035857 (1.835)	-0.00012463 (-1.511)	-0.00078561 (-4.640)	0.00277205 (3.2219	-0.00038732 (-0.911)	-0.02033969 (-8.820)
Retired * expenditure	-0.00242952 (-11.183)	-1.9623E-05 (-0.196)	-0.00287145 (-14.669)	6.2947E-05 (0.065)	0.00246546 (5.180)	-0.02870676 (-11.522)
Total expenditure	0.00673399 (10.710)	-0.00123261 (-4.231)	0.00077153 (1.3429	0.00613085 (2.200)	0.00491098 (3.512)	-0.04483153 (-6.264)
Square total expenditure	-0.00055375 (-7.654)	0.00013123 (4.388)	5.9216E-05 (0.953)	4.3255E-05 (0.138)	-0.00078642 (-5.019)	0.00522809 (6.170)
P Electricity	0,00661308 (12,875)	0,00102309 (4,044)	0,00709901 (13,375)	-0,00618501 (-4,793)	-0,00021321 (-0,228)	-0.00519795 (-6.069)
P Natural gas	0,00102309 (4,044)	0,00371686 (6,372)	-0,00484953 (-6,8559	0,00431005 (5,082)	0,00166914 (2,153)	-0.00510385 (-7.586)
P LPG	0,00709901 (13,375)	-0,00484953 (-6,855)	0,00798891 (4,717)	0,00103918 (0,608)	-0,00459384 (-2,774)	-0.01137084 (-9.799)
P Car fuels	-0,00618501 (-4,793)	0,00431005 (5,082)	0,00103918 (0,608)	0,04053946 (5,956)	-0,00127893 (-0,404)	-0.01687411 (-5.560)
P Public transport	-0,00021321 (-0,228)	0,00166914 (2,153)	-0,00459384 (-2,774)	-0,00127893 (-0,404)	0,01336857 (3,831)	0.00166156 (0.869)
P Food	-0,00519795 (-6,069)	-0,00510385 (-7,586)	-0,01137084 (-9,799)	-0,01687411 (-5,260)	0,00166156 (0,869)	-0.0610984 (-6.467)

Source: own calculations.

Note: t-ratios in brackets.

Table 3. Total expenditure elasticities

Goods	1	2	3	4	5
Panel A. Results with parameter estimates for the whole sample					
Electricity	0.811	0.811	0.891	0.784	0.783
Natural gas	0.899	0.99	---	0.584	1.016
LPG	0.343	0.42	0.363	0.328	0.337
Car fuels	1.798	1.36	2.051	1.850	1.668
Public transport	1.302	1.17	1.357	1.433	1.254
Food	0.600	0.600	0.592	0.576	0.615
Panel B. Results with parameter estimates in sub-samples					
Electricity			0.739	0.649	0.585
Natural gas			1.436	2.244	1.751
LPG			0.517	0.479	0.219
Car fuels			1.973	1.717	1.752
Public transport			0.904	1.082	0.977
Food			0.721	0.684	0.630

Source: Own calculations.

Notes: ***i)*** Panel A: in column 1 we present elasticities at mean values for the whole sample, in column 2 those for the sub-sample of positive expenditures on each good. Columns 3, 4 and 5 respectively report total expenditure elasticities for rural households, households living in towns between 10,000 and 50,000 inhabitants and urban households. ***ii)*** Panel B: Figures in columns 3, 4 and 5 correspond to elasticities at mean values evaluated with parameter estimates obtained in sub-samples by location of the household. They respectively report elasticities for rural households, households living in towns between 10,000 and 50,000 inhabitants and urban households.

Table 4. Own price elasticities

Good	**1**	**2**	**3**	**4**	**5**
Panel A. Results with parameter estimates for the whole sample					
Electricity	-0.797	-0.783	-0.797	-0.795	-0.797
Natural gas	-0.047	-0.046	---	---	-0.445
LPG	-0.367	-0.249	-0.320	-0.325	-0.416
Car fuels	-0.110	-0.058	0.049	-0.087	-0.187
Public transport	-0.106	-0.091	---	0.165	-0.274
Food	-0.422	-0.190	-0.324	-0.310	-0.525
Panel B. Results with parameter estimates in sub-samples					
Electricity			-0.447	-0.749	-0.962
Natural gas			-13.05	-9.997	-0.439
LPG			-0.154	-0.325	-0.630
Car fuels			-0.300	-0.272	0.010
Public transport			-1.490	-0.777	-0.558
Food			-0.716	-0.420	-0.286

Source: Own calculations.

Notes: ***i)*** Panel A: in column 1 we present uncompensated price elasticities at mean values for the whole sample, in column 2 those for the sub-sample of positive expenditures on each good. Columns 3, 4 and 5 respectively report own price elasticities for rural households, households living in towns between 10,000 and 50,000 inhabitants and urban households. ***ii)*** Panel B: Figures in columns 3, 4 and 5 correspond to elasticities at mean values evaluated with parameter estimates obtained in sub-samples by location of the household. They respectively report elasticities for rural households, households living in towns between 10,000 and 50,000 inhabitants and urban households.

Table A1. Descriptive statistics of variables

	1973-95 original sample (anual data)		1973-95 estimation sample (anual data)		units
Number of observations	63,706		51,691		
Variables	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	
Income	5,365	6,480	5,199	5,677	Pesetas (constant)
Total expenditure	5,374	6,184	5,223	5,449	Pesetas (constant)
Electricity	86	113	86	106	Pesetas (constant)
Natural gas	7	43	6	36	Pesetas (constant)
LPG	40	47	40	42	Pesetas (constant)
Car fuels	201	380	191	340	Pesetas (constant)
Public transport	69	214	58	130	Pesetas (constant)
Food	1,584	1,449	1,626	1,398	Pesetas (constant)
Other non-durable	3,387	4,632	3,214	3,893	Pesetas (constant)
Electricity	0.0172	0.0140	0.0166	0.0096	Share %
Natural gas	0.0009	0.0046	0.0008	0.0037	Share %
LPG	0.0116	0.0121	0.0109	0.0087	Share %
Car fuels	0.0290	0.0448	0.0287	0.0415	Share %
Public transport	0.0135	0.0266	0.0121	0.0197	Share %
Food	0.3859	0.1617	0.3885	0.1406	Share %
Other non-durable	0.5419	0.1569	0.5423	0.1356	Share %
No members younger than 15	0.90	1.22	0.94	1.22	Integer number
No members older than 15	2.77	1.23	2.83	1.18	Integer number
Home owner	0.68		0.70		Dummy
Unskilled	0.29		0.27		Dummy
High school	0.10		0.10		Dummy
University	0.06		0.05		Dummy
Rural (inhab.<10,001)	0.28		0.27		Dummy
Village (10,000<inhab.<50,001)	0.20		0.20		Dummy
Urban (inhab.>50,000)	0.52		0.53		Dummy
Retired head	0.25		0.23		Dummy

Source: Own calculations.

Notes: ***i)*** Data statistics are for the original sample so they include households that do not consume some of the goods. ***ii)*** Share refers to the share of each good on total expenditure. ***iii)*** All dummies take value 1 when the event is true and 0 otherwise.