Faculdade de Economia
da Universidade de Coimbra

RITA MARTINS & ADELINO FORTUNATO

**Residential water demand under block
rates – a Portuguese case study**

ESTUDOS DO GEMF
N.º 9   2005

Residential water demand under block rates – a Portuguese case study

Rita Martins
(rvmartin@fe.uc.pt; Tel. 00 351 239790563; Fax 00239403511)
Adelino Fortunato
(adelino@fe.uc.pt; Tel. 00 351 239790563; Fax 00239403511)
Faculdade de Economia da Universidade de Coimbra
Av. Dias da Silva, 165, 3004 – 512 Coimbra, PORTUGAL

Abstract

A residential water demand equation is estimated using a panel data sample of 5 Portuguese local communities and 72 months, corresponding to a total number of 360 observations. Because of the presence of multi-part tariffs, we use as explanatory variables the two common price-related variables: marginal price and *difference*. To prevent the simultaneity bias from using observed quantities to determine the values of marginal price and *difference* directly from the rate schedule, we use an instrumental variable approach to create a constant marginal price and *difference* parameters for each rate structure.

The price elasticity value obtained fall within the range of those found in other case studies. Thus, although presenting weak elasticity, price seems to play a role in water demand management. However, we do not confirm the expected influence of *difference* on residential water demand. This can be a consequence of the complexity of the Portuguese water tariffs and the confusing signs that come from the simultaneous use of fixed quotas and increasing block tariffs. So, it is imperative to clarify water tariffs objectives by reviewing the Portuguese water tariffs design processes.

Key words: demand, water utilities, pricing policy.
JEL Classification Code: L95, Q25

1. Introduction

Recently, it has been widely accepted that the strategy of expanding the supply of water to satisfy increased demand is constrained by the scarcity of water resources. So, there has been a change of approach to water management, from supply-side policies to demand-side ones. Some water sector specificities, such us the universal service obligation, together with the growing concern to induce consumers to use water more efficiently, claim to properly assess the expected effects of pricing policies on water consumption. Estimating household demand for water is, therefore, a prerequisite for any water resource policy design, due to the importance of domestic consumption in an urban context. Many contributions to the analysis of these effects emerge from case studies estimating water demand functions, most of them using United States of America (USA) data.

In the European Union (EU), the Water Framework Directive (Directive 2000/60/EC) recommends the use of tariffs in conjunction with other schemes to promote the rational use of water, such as information/education campaigns, and the reduction of leaks in the systems, as the instruments to be used by a demand based strategy. However, empirical evidence from European countries on the effects of those instruments for managing water is still scarce.

The purpose of this paper is to estimate a Portuguese residential water demand equation in order to explain the effects of the pricing policy on water consumption and to provide those making water allocation decisions in Portugal with relevant and useful information. The residential water demand function is estimated using aggregated data (at the municipal level), collected for each billing period in five municipalities in the Centre Region of Portugal, with panel data estimating techniques.

One point of interest of our case study is that it uses data per billing period instead of the usual utilization of annual data, which is very rare, especially in European studies. Furthermore, another contribution of this empirical application is that we consider sewerage rates, when applicable, together with water supply rates. Thus, if there are any cross-subsidy effects between water and sanitation, they are taken into account by our price-related variables' computed values.

This paper is organized as follows. Section 2 provides an overview of the literature on the estimation of residential water demand, focusing attention on where multi-parts tariff structure applies. In Section 3 some characteristics of Portuguese water supply, water use and pricing are presented. Section 4 is dedicated to the dataset description and methodology.

Results are given in Section 5 and Section 6 contains the conclusions and implications for policy makers.

2. Overview of the literature on water demand

Once water was recognised as a scarce good, it became clear that the strategy to adopt given the growing demand for water could not continuously rely only on the expansion of supply. Therefore, demand side management (DSM) policies have been stimulating significant discussion among water utility managers, policymakers, and economists. Since the 60s, several economists have been discussing the best way to regulate the management of water demand, sustaining their ideas with theoretical and empirical studies dealing with the estimation of residential water demand. The focus of these studies has been to obtain accurate price elasticities of demand.

Although water demand has been extensively studied, most studies, such as Howe and Linaweaver (1967), Gibbs (1978), Danielson (1979), Foster and Beattie (1979), Billings (1982), Schefter and David (1985), Chicoine and Ramamurthy (1986), Moncur (1987), Niesdwiadomy and Molina (1989), Renwick and Archibald (1998) and Renwick and Green (2000), have used data from the USA. However, more recently some studies started to deal with the estimation of residential water demand in some European countries. Examples of this type of literature are Hansen (1996), Höglund (1999), Nauges and Thomas (2000), Martínez-Espiñeira (2003), Garcia and Reynaud (2004) and Martínez-Espiñeira (2004). No study on water demand in relation to Portugal was found except for Martins and Fortunato (2005).

Because it is hard to obtain household level data, the great majority of the studies are based on annual aggregate data (at community level), converted to be used as typical (representative) user level. Despite the consensus found in the literature on the importance of seasonal water demand, intra-annual data are rarely used. An exception is the study by Martínez-Espiñeira (2003), who standardized consumption data from two, three or four month periods, into monthly equivalents.

There is some agreement in the literature on the variables to be taken into account for the residential water demand function. The dependent variable commonly used is the quantity of metered water per household. An exception is Martínez-Espiñeira and Nauges (2004) who used per capita data instead of household data. The explanatory variables found in the literature on this subject can be grouped into two types: non-price and price-related variables.

The former group includes variables such as the size of the household, climate variables, income and other socio-economic variables.

Although there is agreement on the importance of including water price elements in the demand function, the same cannot be said about the specification of the relevant price variable. There is a great debate about the appropriate price variable: average price has been used (Foster and Beatie, 1979; Chicoine and Ramamurthy, 1986; Point, 1993; Nauges and Thomas 2000, among others), as well as marginal price (Howe and Linaweaver, 1967; Gibbs, 1982; Hansen, 1996; Höglund, 1999, among others), and both price measures simultaneously (Gibbs, 1978; Nieswiadomy, 1992).

Under block pricing structures, the choice of the relevant price measure is even more difficult and constitutes one of the most controversial issues encountered in the literature on water demand. In some studies, the authors simplified this problem by ignoring the presence of block rates and using, for example, the first block price (Danielson, 1979 and Moncur, 1987). But most models using block tariffs data (Billings and Agthe, 1980; Billings, 1982; Schefter and David, 1985; Chicoine and Ramamurthy, 1986; Chicoine *et al*, 1986; Nieswiadomy and Molina, 1989; Agthe and Billings, 1996; Renwick and Archibald, 1998, Renwick and Green, 2000; Martínez-Espiñeira, 2003; Martínez-Espiñeira and Nauges, 2004) follow the Taylor (1975) – Nordin (1976) specification, making use of the combination of two price related variables, in order to reflect the tariff structure that the consumer faces.

In his electricity demand study, Taylor (1975) considered that to capture the influence of the block rates both the marginal price for the block in which the household is consuming and the average price should be included. Based on that idea, Nordin (1976) argued that the income effect imposed by the pricing schedule should also be taken into account. An appropriate representation of that effect could be pointed up by the difference between the actual total water bill and what would be paid by customers if every cubic meter of water was purchased at the marginal price. This difference became known as Nordin's *difference* variable (*D*). In notational form,

$$D = p_1 q_1 + \sum_{i=2}^{m} p_i (q_i - q_{i-1}) - p_m q_m \qquad (1)$$

where

q_i - upper volume of consumption in the i block;

p_i - price of the consumption in the ith block;

p_m – marginal price, the price of the consumption in the mth block, the last block;

The coefficient of the *difference* variable should have a negative sign, representing an implicit subsidy or implicit tax that comes from the tariff structure, depending on if there is an increasing or decreasing block structure, respectively. According to Nordin (1976) in linear models this coefficient should be symmetrical but equal in magnitude to the coefficient of income[1].

In addition to the choice of the relevant explanatory price variable, the presence of block rates generates other problems, such as that of simultaneity. In fact, under block pricing schemes it is expected that the marginal water price (p) influences the volume of consumption (q) but p is also determined by the level of consumption, as illustrated by the example in figure 1.

Figure 1 –Specific hypothetical rate schedule with increasing three block rates
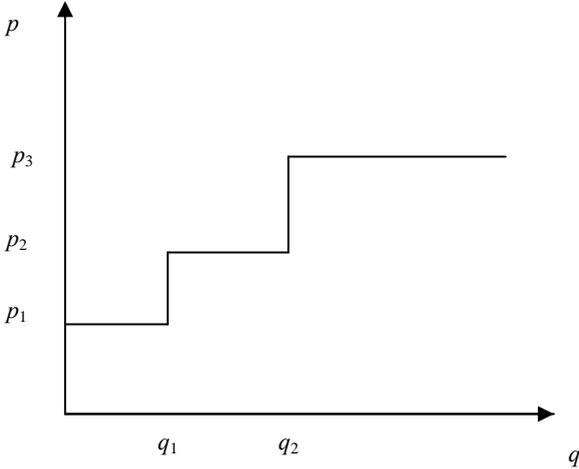
In order to solve the simultaneity problem two types of solutions have been tested. One consists of using instrumental variables estimation techniques, such as two-stage least squares or three-stage least squares, instead of ordinary least squares, as did Niesdwiadomy and Molina (1989) and Renwick and Green (2000), among others. The other type of solution, first applied by Billings (1982) to the water sector and recently used, for example, by Agthe and Billings (1996), Martínez-Espiñeira (2003), and Martínez-Espiñeira and Nauges (2004), consists of creating a linear approximation to the total water bill and then deriving from it a constant marginal price and a constant *difference* parameter for each rate structure, to surpass the simultaneity between price and consume. For this, first a customer's water bill (*BILL*)

---

[1] Although this variable has been included in the specification of several residential water demand models, the magnitude of its effect has not been empirically confirmed.

function is computed for each rate structure, over the range of integer quantities (q) found in the data:

$$BILL = \alpha + \beta q + \mu \qquad\qquad (2)$$

Then, the values of BILL are regressed against corresponding q values to obtain the estimated linear *BILL* function. Its slope, $\hat{\beta} = \partial BILL / \partial q$, corresponds to the estimated instrumental marginal price variable (*IVP*) and $\hat{\alpha}$ is the estimated intercept of the regression equation. Thus, $\hat{\alpha}$ represents the total estimated bill when the quantity demanded is zero, which stands for the difference between what consumers actually pay and what they would pay if all units were sold at marginal price, i.e., the instrumental *difference* variable (*IVD*).

Graphically,

Figure 2 – Customer's water bill and marginal price for a specific rate structure and its linear estimate
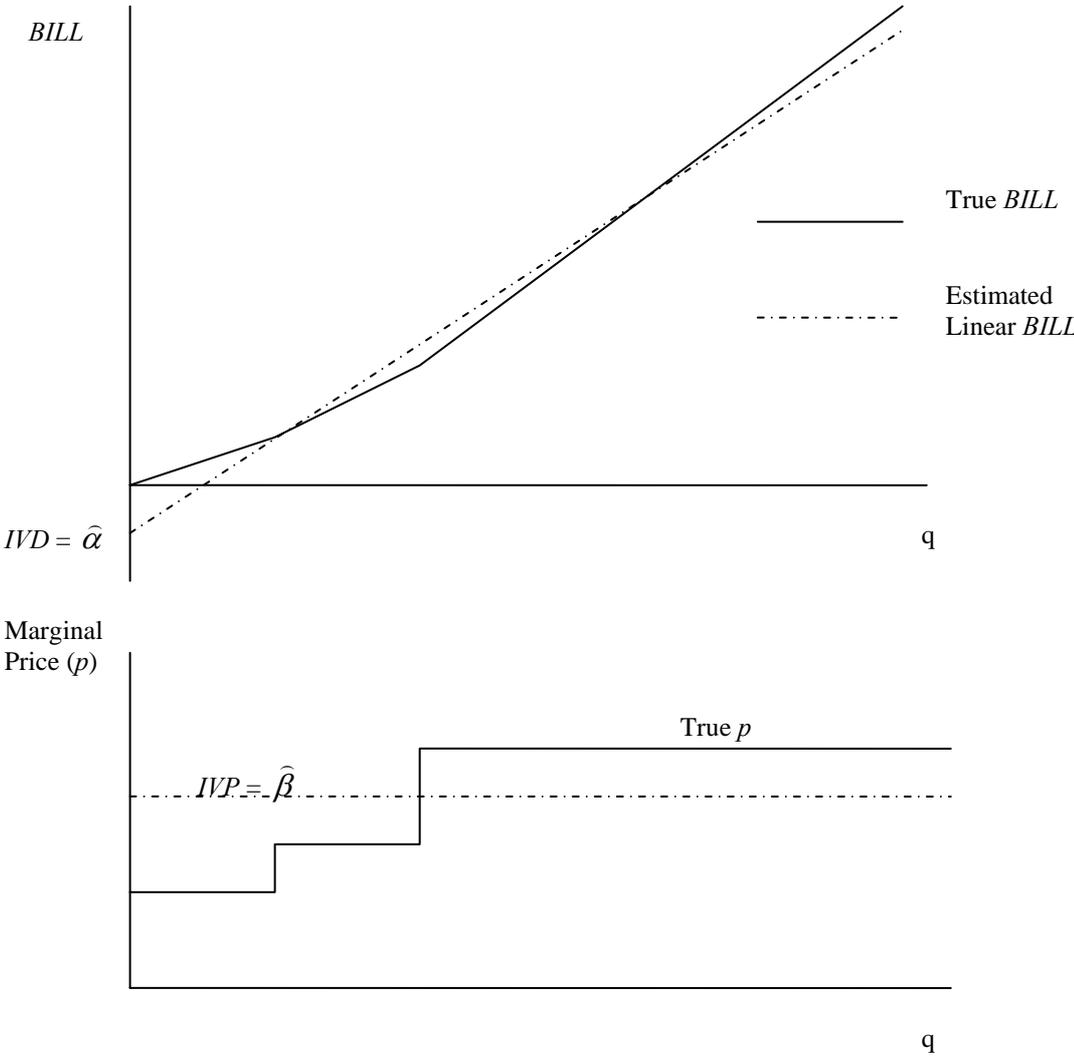
Adapted from Billings (1982:388)

Despite the differences among the studies, there are similarities in terms of the findings. One common output is the sign and magnitude of the effect of water price on water demand. Usually, there is an agreement that price has a negative effect on a household's water consumption but that the price elasticity of demand is weak. Among the justifications for these results there is the small proportion of the budget related to water expenditure and the lack of close substitutes for water, together with the fact that water is vital, especially for inside uses. When it was possible to estimate "*winter or in-house demand*" and "*sprinkling or summer demand*" separately, authors such as Howe and Linaweaver (1967), Danielson (1979), Hansen (1996), Agthe and Billings (1996), Renwick and Archibald (1998), showed a different influence of price, which was its comprehensively greater effect on "*sprinkling or summer demand*".

Moreover, positive effects of variables such as income and size of the household on water consumption are widely accepted.

Finally, among the explanatory variables, climatic ones are frequently tested in the empirical literature on water demand.

3. Water supply, water use and pricing in some municipalities in the Centre Region of Portugal

Before trying to estimate and test any model of water demand in Portugal it is important to be aware of some characteristics of the Portuguese water market.

The area of the study comprises five municipalities in the Centre Region of Portugal. In 2003 the water utilities operating in this area provided water supply to 98% of the population in their local communities. In addition to the residential and services segment, water utilities serve industrial, commercial and other demands. However, data from INE (2002) indicates that residential and services consumption represents almost 73% of the total amount supplied by the public network in the area studied in 2003, which is very similar to the figure of 74% in the whole of Portugal. Data from the water operators reveal that households consume almost 70% of the total water supplied in the municipalities studied.

Data from official population estimates - INE (2003) and operators, show an increase of domestic water consumption, from 112 litres in 2001 to 137 litres per person per day in 2003, or from 281 in 2001 to 325 litres per domestic meter in 2003.

With respect to network losses, computed as the weight of the difference between the volume of water produced and distributed on the volume of water produced (APDA, 2004), assume a problematic value around 30% in the local communities studied.

The market structure for the Portuguese water sector can be characterized as local (municipal) natural monopolies, with heterogeneity of institutional arrangements in water supply and wastewater. Portuguese local communities have been responsible for water supply, treatment and sanitation since the 70s. Although responsible for the satisfactory operation of local water services, in practice municipalities can decide to operate water utilities by themselves or to delegate it to a company, by a concession process. In this last case, the private sector can participate in the Portuguese water industry. Thus, water supply and sanitation can be provided in Portugal directly by local public water authorities, (under municipal services, *municipalized* services[2] or municipal public firms-MPF) or by companies, which interact as concessionaries of the systems.

In the municipalities studied, there are no management forms other than municipal or *municipalized* services, except for one municipality where the transformation of such a type of service into a MPF occurred during the observation period.

Contrary to the great majority of European countries, since 1997 there has been a centralized public authority in charge of regulating the water supply and wastewater services in Portugal. But its jurisdiction in the field of setting prices is limited to issuing non-binding opinions about price regimes, and only when it comes to services delegated to private operators. But, even in these cases, the price system is one criterion for the selection of the contestants, so it is regulated by the concession contract. Therefore, the regulator's powers are restricted to making recommendations on the proposed prices, and only if the service is provided by a concessionaire, which reveals a weak power of intervention.

In the other cases, prevailing throughout the studied area, each community makes its own decision on the price setting (level and structure) process, and that decision is only subject to approval by the municipal assembly. However, the overwhelming opinion in Portugal is that prices are underestimated and do not covers even the operating costs. In relation to this, there is a consensus among specialists about the need to change the way tariffs are set in order to meet the Water Framework Directive stipulations, i.e., to take into account of the principle of recovery of the costs of water services, including environmental and resource costs, in accordance with the polluter pays principle.

---

[2] These services, unlike municipal ones, have financial and managing autonomy although without a legal standard.

Generally, a water bill has three components: one is related to the supply process, another to the sanitation services and a third component corresponds to taxes. Most communities use a water price divided into one variable part and one fixed part. Regardless of the type of management, water is usually sold to Portuguese residential users under increasing block rates. Thus, Portuguese households face a multi-part tariff, which consists of several elements: a fixed charge, also known as availability of service charge, for being connected to the water supply system (which must be paid even if no water is consumed) and to the sewerage system, and one or more elements resulting from one or more prices per cubic meter (usually known as a volumetric rates) times the total amount consumed or parts of the total volume consumed.

Often, there are several blocks in each municipality, with each block being defined by lower and upper (except for the top block) volumes of consumption. The usual number of blocks applied in each municipality in Portugal varies between 3 and 6, *inclusive*. Three municipalities used in our study have three blocks, one has four and, and one has six blocks. In all cases we found availability of service charges and increasing block rates, which mean that volumetric rates rise as more water is consumed.

Therefore, excluding taxes, the rule for determining a water bill (water supply plus sewerage) for a quantity, q_3, of water consumed in a municipality where 3 blocks are defined is:

$$Bill = (CC + SC) + q_1 \times p_{ws1} + (q_2 - q_1) \times p_{ws2} + (q_3 - q_2) \times p_{ws3} + q_3 \times p_{ww} \qquad (3.a)$$

where

CC - fixed connection charge;

SC - fixed sewerage charge;

q_i - upper volume of consumption in the i block;

p_{wsi} - price of the consumption in the ith block;

p_{ww} - price related to wastewater services.

However, as a consequence of the lack of effective price regulation, each municipality has its own price scheme. In some situations, there was an adjustment on the dimension and number of blocks, throughout the period of the analysis. There are other differences besides the differences in the number and dimension of blocks. In relation to the payment of water supply services, among the operators having three blocks, in the first years of the analysis two

local communities applied only one price to the total amount of water consumed, according to the block where that volume belongs, and another local water authority, did the same during the entire period. In such cases equation (3.a) becomes:

$$Bill = (CC + SC) + q_3 \times p_{ws3} + q_3 \times p_{ww} \tag{3.b}$$

Concerning the sanitation process, in our group of five municipalities, one was found to have no payment for these types of services (no SC and no $q_i \times p_{ww}$). Another exception is one case where the SC is defined according to the amount of water consumed and in this case $q_i \times p_{ww}$ does not exist. Finally, another difference occurs in one case where p_{ww} applies to eighty percent of the volume of water consumed.

In order to have some idea of differences between municipalities in terms of prices, marginal prices based on a monthly residential consumption of 10 m^3 of water were computed. Their values are presented in table 1.

Table 1 – Marginal price of the 10th cubic meter of water consumed

	Municipality 1	Municipality 2	Municipality 3	Municipality 4	Municipality 5
1998	0.486	0.462	0.632	0.545	0.365
1999	0.485	0.461	0.617	0.561	0.356
2000	0.582	0.457	0.601	0.564	0.370
2001	0.576	0.447	0.576	0.557	0.354
2002	0.402	0.453	0.616	0.555	0.385
2003	0.389	0.465	0.613	0.552	0.455

All prices are expressed in constant escudos (PTE) from 1997, translated to euro equivalents (1€= 200.482 PTE).

Besides marginal prices borne for the same quantity differing between municipalities, it is also interesting to point up the decrease in real marginal prices that occurs in some cases, during the period.

4. Dataset description and methodology

We used a panel data sample of 5 municipalities and 72 months, from January 1998 to December 2003, corresponding to a total number of 360 observations.

Information on residential water consumption and its respective prices was requested from the operators of water utilities. More precisely, we asked for data on tariff schemes (number and dimension of blocks, volumetric rates and fixed charges) for domestic water supply, total domestic use and number of domestic accounts per billing period. We also

requested data on tariffs for sewerage services, if applicable, in order to obtain the value of the water bill.

The billing periods are either one or two months. Therefore, data on domestic consumption was standardized into monthly equivalents, by assuming that, when bimonthly billing period applies, consumption during that period was constant.

Because data obtained on domestic consumption was aggregated at community level, we constructed the explained variable – monthly water consumption per typical (representative) household in a local community – by dividing total domestic consumption by the number of domestic accounts (number of residential customers).

Data on consumption and the tariff schedules applied in each period were combined to obtain the price-related explanatory variables. Since multipart tariff structures are used in all municipalities, we followed the Taylor (1975)–Nordin (1976) specification for the marginal price and *difference* variable. In order to prevent the simultaneity bias from using observed quantities to determine the values of marginal price and *difference* directly from the rate schedule, we considered the suggestion proposed by Billings (1982) to compute a constant marginal price and *difference* parameter for each rate structure (for each municipality and for each year).

Our instrumental variable approach started by using (3.a) or (3.b) to compute the values of the theoretical water bills, associated with all integer values of monthly water use per account between $2m^3$ and $17m^3$ (which we consider the reasonable range of typical household consumption based on the data used and empirical literature reviewed). Then, we estimated the water bill functions (one to each rate schedule) regressing the theoretical water bill values linearly against the corresponding integer values of monthly water use per account (q). As mentioned before, *ivp* is the slope and *ivd* is the intercept of the estimated function[3], and they do not vary with observed quantities which means that we derived the constant instrumental marginal price (*ivp*) and instrumental *difference* (*ivd*) parameters.

However, due to the fact that water prices are reviewed only once a year, or less, the Billing variables, *ivp* and *ivd*, would be constant for 12 or more months, for each municipality. Thus, using a monthly retail price index series we did a deflation adjustment and computed the monthly *ivp* and *ivd* variables.

To find out if consumers react to the penalization imposed by the fact that only one block price applies to every cubic meter consumed (equation 3.b), we used a dummy variable,

---

[3] See, in Section 2, Billings (1982) suggestion for solving the simultaneity bias which tend to occur under block rate tariffs.

dumc, which takes the value 1 in this case and the value 0 if several block prices are applied (equation 3.a).

Several sources provided the data on socio-economic and climate variables. Some socio-economic variables came from the 2001 Portuguese Census and, therefore there is no within-unit variability for these variables: they vary only cross-sectionally. In this group of variables we include the number of residents per household (*numres*) and percentage of people over 65 (*ov65*). The influence of this last variable on water consumption was suggested and tested by Nauges and Thomas (2000) and by Martínez-Espiñeira (2003).

Because there was no monthly data available on typical household income, we followed one procedure used by INE to compute the purchasing power indexes, calculating automatic teller machines withdrawals per capita (*inc*) and deflating it to be used as a proxy for the income variable.

Finally, information on climate variables (from the closest station to each municipality) was collected from AGRIBASE and includes information on precipitation and temperature. The values used for these variables are their normal values per month, computed as historical (long-term) averages for a period of 30 years. They vary per month and per municipality.

The definition of the variables used and a summary of some statistics can be found in Table 2.

Table 2 – List of variables

Variables	Definition (unit)	Type	Mean	Standard deviation	Minimum	*Maximum*
Dependent						
Q	Water consumption of the typical family (m$^{3)}$)	CS-TS	8.592	1.9716	4.6361	15.58668
Independents						
Ivp	Instrumental variable for water (plus sewerage) marginal price (€1997)	CS-TS	0.688	0.1149	0.4692	0.9062
Ivd	Instrumental variable for *difference* variable(€1997)	CS-TS	1.335	0.7411	0.3690	2.7286
Dumc	Dummy variable (1 if the price applies to all cubic metres; 0 otherwise)	CS-TS	0.333	0.4721	0	1
Inc	Proxy variable for income (€1997)		107.07	37.5754	12.8583	208.9297
Numres	Number of residents per household	CS	2.52	0.2138	2.2	2.8
ov65	Percentage of people over 65	CS	0.167	0.01913	0.1461	0.1954
Temp	Normal maximum monthly air temperature (ºC)	CS-TS	13.895	4.5297	3.6	20.9
Prec	Normal monthly precipitation (mm)	CS-TS	82.858	45.160	6.2	148.6

CS stands for cross-section and TS for time series.

According to the literature, *ivp*, *ivd*, *prec*, *ov65* and *dumc* were hypothesized to be negatively correlated with residential water use whereas *inc*, *numres* and *temp* were hypothesized to be negatively correlated.

Given the contribution of studies conducted in the field of water demand, data availability and the transformation we have made to obtain certain variables, the following demand equation is postulated and estimated:

$$q_{it} = \beta_0 + \beta_1 ivp_{it} + \beta_2 ivd_{it} + \beta_3 dumc_{it} + \beta_4 inc_{it} + \beta_5 numres_i + \beta_6 ov65_i + \beta_7 temp_{it} + \beta_8 prec_{it} + \varepsilon_{it} \quad (4)$$

where $i=1, 2, \ldots, 5$ is the index which identifies each municipality and $t=1, 2, \ldots, 72$ denotes time period. $\varepsilon_{it} = \mu_i + \upsilon_{it}$ refers to the error term. The μ_i component is a community specific error term, and reflects spatial unexplained variation while the υ_{it} component reflects all (spatial and temporal) residual unexplained variation. Both error terms are assumed to be normally distributed with zero mean and constant variance.

The result of the Hausman test favoured the specification of the random effect model over the specification of the fixed effect model. Thus, we considered a random effects model, which requires the generalized least squares (GLS) estimation method. Equation (4) is assumed to be linear and estimated using a GLS approach, with a correction for a 1ˢᵗ-order autoregressive disturbance process[4], to obtain the β coefficients using panel data.

5. Results

The GLS estimation results, using the *software* STATA 8.0, for water demand equation are shown in Table 3.

---

[4] Using the "xtregar" instruction, from the software STATA 8.0.

Table 3 – Results of the estimated residential demand equation

Variable	Estimated coefficient	Z Statistic
Constant	10.22722	3.48*
Ivp	-6.976089	-6.34*
Ivd	0.7730964	4.18*
Dumc	0.6718489	2.90*
Inc	-0.00046	-0.13
Numres	1.481168	2.60*
Ov65	-34.85687	-5.27*
Temp	0.1978384	6.01*
Prec	0.0046476	1.36
Adjusted R² 0.6920		

* Significant at a 1% level of significance.

The adjusted R^2 indicates an acceptable model performance.

The coefficient on the marginal price is statistically significant and presents the expected negative signal. Because of the hypothesis of the linear demand curve assumed, the price elasticity varies with price and typical household use levels. Thus, if we consider the average marginal price and average water use we obtain an elasticity value of -0,558, which falls within the ranges of those found in the literature.

The derivative of water use with respect to *difference* variable is statistically significant but shows an unexpected positive sign. Despite the water utilities' preference for increasing block rates, due to the fixed charges' values the series for D variable always assumed positive values[5]. This positive sign for D represents a negative income effect for the water customer derived from the tariff structure. An increase in D should, therefore, cause a reduction in water use.

The positive sign of the D coefficient may be due to the fact that fixed quotas work against water conservation purpose, distorting the pro-conservation incentive pursued by the increasing tariffs. Thus, it becomes clear the residential consumer's difficulties in interpreting the price schedule become clear and it is not surprising that they do not react as we anticipated.

In accordance with the above explanation, *Dumc* does not show the expected negative sign, which means that consumers do not react to price schemes that penalize high water consumption levels more (by charging the same high price for every cubic meter consumed) by cutting consumption (saving water).

The estimation results also indicate that, except for precipitation and income, all the other coefficients have significant effects on residential water consumption. The estimated

---

[5] See Table 2 in the previous section.

coefficient of the variable used here as a proxy for income is not statistically significant. This result can be explained since water accounts for a small proportion of disposable family income, due to the low levels of water prices.

The size of the household and the percentage of old people estimated coefficients exhibit the expected signs. The positive coefficient of *numres* means that where the household is large, consumption will also be high. The negative sign of the *ov65* means that a higher proportion of elderly people can result in lower average use of water.

The air temperature variable is positively correlated with residential water demand and its coefficient is statistically significant, suggesting that high temperatures increase the demand for water. The fact that the rainfall variable does not reveal statistical significance is not surprising since the *prec* variable presents a positive sign, which was not expected.

6. Conclusions and policy implications

There is some consensus among water utility managers, policymakers, and economists on the relevance of water price as an instrument to be used by DSM policies. Accordingly, literature on residential water demand shows that in spite of weak price elasticities, there is a negative influence of water price on water consumption. Furthermore, it is also accepted that non-price policies, such as the promotion of low-consumption equipment, awareness campaigns and educational programs, should also be considered as means of controlling demand.

The results obtained in the present study agree in some aspects with other case studies on residential water demand. In the studied area, the marginal price varies with the amount of water used (the practice of increasing block rates is the rule) and domestic water demand appears to be negatively influenced by marginal prices. Water pricing therefore seems to be useful to help in the rationalization of water use. Nevertheless, the result achieved for marginal price elasticity of residential water demand should be viewed with caution. Negative price elasticity can also be a consequence of a general tendency for water demand to increase, along with a fall in water prices in real terms (in several cases they rose less than inflation rates).

Moreover, the way water prices are determined means that they send confusing signals to consumers. The water tariff data that we collected revealed complex structures that combine several components, and they therefore distort the ability of domestic consumers to

relate the size of the bill to the volume of water purchased. The main source of confusion comes simultaneously from the generalized use of availability of service charges and increasing block rates, because of their contradictory role. The employment of increasing block tariffs is justified because it is appropriate to the goal of conserving water resource, since if more water is consumed, then successively higher prices are faced (penalization of high consumption). On the other hand, the presence of fixed charges (to be connected to the supply and sewerage systems) implies that increasing water use allows these fixed amounts to be distributed in a large number of cubic meters. This complexity/contradiction may well explain the unexpected coefficient sign obtained for the *difference* variable.

Finally, it is important to take into account that increasing water prices to control demand should not ignore the imperative of the universal service obligation, at least in relation to the minimum quantities considered vital for human life. On top of all this, attention must be paid to the fact that increasing block tariffs penalizes households with numerous members, as a result of the positive influence of the size of the household (*numres* variable) on residential water demand.

Summarizing, it seems clear that the effects of water prices on demand can be improved by making consumers more aware of how their consumption affects their water bill. To this end, it is imperative to clarify the signals sent by the individual components of the tariff. One interesting way to promote adequate pricing policies in the Portuguese water sector could be to give the existing regulatory authority powers to intervene in the price setting process and to manage the potential conflict between efficiency and equity.

References

Agthe, Donald and Billings, Bruce (1996), "Water-Price Effect on Residential and Apartment Low-Flow Fixtures", *Journal of Water Resources Planning and Management*, Jan-Feb, pp. 20–23.

APDA (2004), *Quem é quem no sector das Águas em Portugal*, Lisboa, Associação Portuguesa de Distribuição e Drenagem de Águas.

Arbués, Fernando; Garcia-Valiñas, Maria A. and Martínez-Espiñeira, Roberto (2003), "Estimation of residential water demand: a state-of-the-art review, *Journal of Socio-Economics*, 32, pp.81-102.

Billings, R. Bruce and Agthe, E. (1980), "Price Elasticities for Water: A case of Increasing Block Rates", *Land Economics* 56(1), February, pp. 73-84.

Billings, R. Bruce (1982), "Specification of Block Rate Price Variables in Demand Models", *Land Economics* 58(3), August, pp. 386-394.

Chicoine, David L. and Ramamurthy, Ganapathi (1986), "Evidence on the Specification of Price in the Study of Domestic Water Demand", *Land Economics*, 62(1), February, pp26-32.

Chicoine, David L.; Deller, Steven, and Ramamurthy, Ganapathi (1986), "Water Demand Estimation Under Block Rate Pricing: A Simultaneous equation Approach", 62(1), *Water Resources Research*, vol 22 (6), pp.859-863.

Danielson, Leon E. (1979), "An Analysis of Residential Demand for Water Using Micro Time-Series Data", *Water Resources Research*, vol 15(4), pp.763-767.

(DGCI, 2003), available at http://www.dgci.pt

Foster, Henry S. and Beattie, Bruce R. (1979), "Urban Residential Demand for Water in the United States", *Land Economics*, 55(1), February, pp.43-58.

Garcia, Serge and Reynaud, Arnaud (2004), "Estimating the benefits of efficient water pricing in France", *Resource and Energy Economics*, 26, pp.1-25.

Gibbs, Kenneth (1978), "Price Variable in Residential Water Demand Models", *Water Resources Research*, vol 14(1), pp.15-18.

Griffin, Ronald C. and Chang, Chan (1990), "Pretest Analyses of Water Demand in Thirty Communities", *Water Resources Research*, vol 26(10), pp.2251-2255.

Hansen, Lars G. (1996), "Water and Energy Price Impacts on Residential Water Demand in Copenhagen", *Land Economics*, February, vol. 72 (1), pp. 66-79.

Howe, C. and Linaweaver, F. (1967), "The Impact of Price on Residential Water Demand and its Relation to System Design and Price Structure", *Water Resources Research*, vol 3 (1), pp. 13-32.

Höglund, Lena (1999), "Household demand for water in Sweden with implications of a potential tax on water use", *Water Resources Research*, vol. 35(12), pp.3853-3863.

INE (2003), Estimativas de População Residente, Grandes Grupos Etários e Índices em 31/XII/2003, available at http://www.ine.pt.

INE (2002), Estatísticas do Ambiente, 2002, available at http://www.ine.pt.

MAOT (2001), *Plano Nacional da Água*, Lisboa, Ministério do Ambiente e do Ordenamento do Território.

Martínez-Espiñeira, Roberto and Nauges, Celine (2004), "Is all domestic water consumption sensitive to price control", *Applied Economics*, 36, pp.1697-1703.

Martínez-Espiñeira, Roberto (2003), "Estimating Water Demand under Increasing-Block Tariffs Using Aggregate Data and Proportions of Users per Block", *Journal of Environmental Economics and Management*, 26, pp.5-23.

Martínez-Espiñeira, Roberto (2003), "Price specifications issues under block tariffs: a Spanish case study", *Water policy*, 5, pp.237-256.

Martins, Rita and Fortunato, Adelino (2005), "A procura residencial de água em Portugal: preços como instrumento de gestão de procura?", *Tecnologia da Água*, 6, Maio 2005, pp. 14-28.

Moncur, James E.T. (1987), "Urban Water Pricing and Drought Management", *Water Resources Research*, vol 23 (3), pp.393-398.

Niesdwiadomy, Michael L and Molina, David J. (1989), "Comparing Residential Water Demand Estimates under Decreasing and Increasing Block Rates using Household Data", *Land Economics*, 65(3), August, pp 281-289.

Nauges, Céline and Thomas, Alban (2000), "Privately Operated Water Utilities, Municipal Price Negotiation, and Estimation of residential Water Demand: The Case of France", *Land Economics*, February, vol. 76 (1), pp. 68-85.

Nordin, J. A. (1976), "A Proposed Modification of Taylor's Demand Analysis: Comment", *The Bell Journal of Economics*, 7, pp. 719-721.

Opaluch, James J. (1982), "Urban Residential Demand for Water in the United States: Further Discussion", Land Economics, 58(2), May, pp.225-227

Renwick, Mary E. and Archibald, Sandra O. (1998), "Demand Side Management Policies for Residential Water Use: Who Bears the Conservation Burden?", *Land Economics*, August, vol. 74 (3), pp. 343-59.

Renwick, Mary E. and Green, Richard D. (2000), "Do residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies", *Journal of Environmental Economics and Management*, 40, pp. 37-55.

Renzetti, Steven (1992), "Evaluating the Welfare Effects of Reforming Municipal Water Prices", *Journal of Environmental Economics and Management*, 22, pp.147-163.

Schefter, J. E. and David, L.E. (1985), "Estimating Residential Water Demand Under Multi-Part Tariffs Using Aggregate Data", *Land Economics*, 61(3), August, pp.272-280.

Taylor, Lester D. (1975), "The Demand for electricity: A Survey", *The Bell Journal of Economics*, 6(1), pp. 74-110.

ESTUDOS DO G.E.M.F.

(Available on-line at http://gemf.fe.uc.pt)

2005-09 *Residential water demand under block rates – a Portuguese case study*
- Rita Martins & Adelino Fortunato

2005-08 *Politico-Economic Causes of Labor Regulation in the United States: Alliances and Raising Rivals' Costs (and Sometimes Lowering One's Own)*
- John T. Addison

2005-07 *Firm Growth and Liquidity Constraints: A Dynamic Analysis*
- Blandina Oliveira & Adelino Fortunato

2005-06 *The Effect of Works Councils on Employment Change*
- John T. Addison & Paulino Teixeira

2005-05 *Le Rôle de la Consommation Publique dans la Croissance: le cas de l'Union Européenne*
- João Sousa Andrade, Maria Adelaide Silva Duarte & Claude Berthomieu

2005-04 *The Dynamics of the Growth of Firms: Evidence from the Services Sector*
- Blandina Oliveira & Adelino Fortunato

2005-03 *The Determinants of Firm Performance: Unions, Works Councils, and Employee Involvement/High Performance Work Practices*
- John T. Addison

2005-02 *Has the Stability and Growth Pact stabilised? Evidence from a panel of 12 European countries and some implications for the reform of the Pact*
- Carlos Fonseca Marinheiro

2005-01 *Sustainability of Portuguese Fiscal Policy in Historical Perspective*
- Carlos Fonseca Marinheiro

2004-03 *Human capital, mechanisms of technological diffusion and the role of technological shocks in the speed of diffusion. Evidence from a panel of Mediterranean countries*
- Maria Adelaide Duarte & Marta Simões

2004-02 *What Have We Learned About The Employment Effects of Severance Pay? Further Iterations of Lazear et al.*
- John T. Addison & Paulino Teixeira

2004-01 *How the Gold Standard Functioned in Portugal: an analysis of some macroeconomic aspects*
- António Portugal Duarte & João Sousa Andrade

2003-07 *Testing Gibrat's Law: Empirical Evidence from a Panel of Portuguese Manufacturing Firms*
- Blandina Oliveira & Adelino Fortunato

2003-06 *Régimes Monétaires et Théorie Quantitative du Produit Nominal au Portugal (1854-1998)*
- João Sousa Andrade

2003-05 *Causas do Atraso na Estabilização da Inflação: Abordagem Teórica e Empírica*
- Vítor Castro

2003-04 *The Effects of Households' and Firms' Borrowing Constraints on Economic Growth*
- Maria da Conceição Costa Pereira

2003-03 *Second Order Filter Distribution Approximations for Financial Time Series with Extreme Outliers*
- J. Q. Smith & António A. F. Santos

2003-02 *Output Smoothing in EMU and OECD: Can We Forego Government Contribution? A risk sharing approach*
- Carlos Fonseca Marinheiro

2003-01 *Um modelo VAR para uma Avaliação Macroeconómica de Efeitos da Integração Europeia da Economia Portuguesa*
- João Sousa Andrade

2002-08 *Discrimination des facteurs potentiels de croissance et type de convergence de l'économie portugaise dans l'UE à travers la spécification de la fonction de production macro-économique. Une étude appliquée de données de panel et de séries temporelles*
- Marta Simões & Maria Adelaide Duarte

2002-07 *Privatisation in Portugal: employee owners or just happy employees?*
-Luís Moura Ramos & Rita Martins

2002-06 *The Portuguese Money Market: An analysis of the daily session*
- Fátima Teresa Sol Murta

2002-05 *As teorias de ciclo políticos e o caso português*
- Rodrigo Martins

2002-04 *Fundos de acções internacionais: uma avaliação de desempenho*
- Nuno M. Silva

2002-03 *The consistency of optimal policy rules in stochastic rational expectations models*
- David Backus & John Driffill

2002-02 *The term structure of the spreads between Portuguese and German interest rates during stage II of EMU*
- José Soares da Fonseca

2002-01 *O processo desinflacionista português: análise de alguns custos e benefícios*
- António Portugal Duarte

2001-14 *Equity prices and monetary policy: an overview with an exploratory model*
- Fernando Alexandre & Pedro Bação

2001-13 *A convergência das taxas de juro portuguesas para os níveis europeus durante a segunda metade da década de noventa*
- José Soares da Fonseca

2001-12 *Le rôle de l'investissement dans l'éducation sur la croissance selon différentes spécifications du capital humain.*
- Adelaide Duarte & Marta Simões

2001-11 *Ricardian Equivalence: An Empirical Application to the Portuguese Economy*
- Carlos Fonseca Marinheiro

2001-10 *A Especificação da Função de Produção Macro-Económica em Estudos de Crescimento Económico.*
- Maria Adelaide Duarte e Marta Simões

2001-09 *Eficácia da Análise Técnica no Mercado Accionista Português*
- Nuno Silva

2001-08 *The Risk Premiums in the Portuguese Treasury Bills Interest Rates: Estimation by a cointegration method*
- José Soares da Fonseca

2001-07 *Principais factores de crescimento da economia portuguesa no espaço europeu*
- Maria Adelaide Duarte e Marta Simões

2001-06   *Inflation Targeting and Exchange Rate Co-ordination*
            - Fernando Alexandre, John Driffill e Fabio Spagnolo

2001-05   *Labour Market Transition in Portugal, Spain, and Poland: A Comparative Perspective*
            - Paulino Teixeira

2001-04   *Paridade do Poder de Compra e das Taxas de Juro: Um estudo aplicado a três países da UEM*
            - António Portugal Duarte

2001-03   *Technology, Employment and Wages*
            - John T. Addison & Paulino Teixeira

2001-02   *Human capital investment through education and economic growth. A panel data analysis based on a group of Latin American countries*
            - Maria Adelaide Duarte & Marta Simões

2001-01   *Risk Premiums in the Porutguese Treasury Bills Interest Rates from 1990 to 1998. An ARCH-M Approach*
            - José Soares da Fonseca

2000-08   *Identificação de Vectores de Cointegração: Análise de Alguns Exemplos*
            - Pedro Miguel Avelino Bação

2000-07   *Imunização e M-quadrado: Que relação?*
            - Jorge Cunha

2000-06   *Eficiência Informacional nos Futuros Lisbor 3M*
            - Nuno M. Silva

2000-05   *Estimation of Default Probabilities Using Incomplete Contracts Data*
            - J. Santos Silva & J. Murteira

2000-04   *Un Essaie d'Application de la Théorie Quantitative de la Monnaie à l'économie portugaise, 1854-1998*
            - João Sousa Andrade

2000-03   *Le Taux de Chômage Naturel comme un Indicateur de Politique Economique? Une application à l'économie portugaise*
            - Adelaide Duarte & João Sousa Andrade

2000-02   *La Convergence Réelle Selon la Théorie de la Croissance: Quelles Explications pour l'Union Européenne?*
            - Marta Cristina Nunes Simões

2000-01   *Política de Estabilização e Independência dos Bancos Centrais*
            - João Sousa Andrade

1999-09   *Nota sobre a Estimação de Vectores de Cointegração com os Programas CATS in RATS, PCFIML e EVIEWS*
            - Pedro Miguel Avelino Bação

1999-08   *A Abertura do Mercado de Telecomunicações Celulares ao Terceiro Operador: Uma Decisão Racional?*
            - Carlos Carreira

1999-07   *Is Portugal Really so Arteriosclerotic? Results from a Cross-Country Analysis of Labour Adjustment*
            - John T. Addison & Paulino Teixeira

1999-06   *The Effect of Dismissals Protection on Employment: More on a Vexed Theme*
            - John T. Addison, Paulino Teixeira e Jean-Luc Grosso

1999-05 *A Cobertura Estática e Dinâmica através do Contrato de Futuros PSI-20. Estimação das Rácios e Eficácia Ex Post e Ex Ante*
 - Helder Miguel C. V. Sebastião

1999-04 *Mobilização de Poupança, Financiamento e Internacionalização de Carteiras*
 - João Sousa Andrade

1999-03 *Natural Resources and Environment*
 - Adelaide Duarte

1999-02 *L'Analyse Positive de la Politique Monétaire*
 - Chistian Aubin

1999-01 *Economias de Escala e de Gama nos Hospitais Públicos Portugueses: Uma Aplicação da Função de Custo Variável Translog*
 - Carlos Carreira

1998-11 *Equilíbrio Monetário no Longo e Curto Prazos - Uma Aplicação à Economia Portuguesa*
 - João Sousa Andrade

1998-10 *Algumas Observações Sobre o Método da Economia*
 - João Sousa Andrade

1998-09 *Mudança Tecnológica na Indústria Transformadora: Que Tipo de Viés Afinal?*
 - Paulino Teixeira

1998-08 *Portfolio Insurance and Bond Management in a Vasicek's Term Structure of Interest Rates*
 - José Alberto Soares da Fonseca

1998-07 *Financial Innovation and Money Demand in Portugal: A Preliminary Study*
 - Pedro Miguel Avelino Bação

1998-06 *The Stability Pact and Portuguese Fiscal Policy: the Application of a VAR Model*
 - Carlos Fonseca Marinheiro

1998-05 *A Moeda Única e o Processo de Difusão da Base Monetária*
 - José Alberto Soares da Fonseca

1998-04 *La Structure par Termes et la Volatilité des Taux d'intérêt LISBOR*
 - José Alberto Soares da Fonseca

1998-03 *Regras de Comportamento e Reformas Monetárias no Novo SMI*
 - João Sousa Andrade

1998-02 *Um Estudo da Flexibilidade dos Salários: o Caso Espanhol e Português*
 - Adelaide Duarte e João Sousa Andrade

1998-01 *Moeda Única e Internacionalização: Apresentação do Tema*
 - João Sousa Andrade

1997-09 *Inovação e Aplicações Financeiras em Portugal*
 - Pedro Miguel Avelino Bação

1997-08 *Estudo do Efeito Liquidez Aplicado à Economia Portuguesa*
 - João Sousa Andrade

1997-07 *An Introduction to Conditional Expectations and Stationarity*
 - Rui Manuel de Almeida

1997-06 *Definição de Moeda e Efeito Berlusconi*
 - João Sousa Andrade

1997-05 *A Estimação do Risco na Escolha dos Portafólios: Uma Visão Selectiva*
 - António Alberto Ferreira dos Santos

1997-04 *A Previsão Não Paramétrica de Taxas de Rentabilidade*
       - Pedro Manuel Cortesão Godinho

1997-03 *Propriedades Assimptóticas de Densidades*
       - Rui Manuel de Almeida

1997-02 *Co-Integration and VAR Analysis of the Term Structure of Interest Rates: an empirical study of the Portuguese money and bond markets*
       -João Sousa Andrade & José Soares da Fonseca

1997-01 *Repartição e Capitalização. Duas Modalidades Complementares de Financiamento das Reformas*
       - Maria Clara Murteira

1996-08 *A Crise e o Ressurgimento do Sistema Monetário Europeu*
       - Luis Manuel de Aguiar Dias

1996-07 *Housing Shortage and Housing Investment in Portugal a Preliminary View*
       - Vítor Neves

1996-06 *Housing, Mortgage Finance and the British Economy*
       - Kenneth Gibb & Nile Istephan

1996-05 *The Social Policy of The European Community, Reporting Information to Employees, a U.K. perspective: Historical Analysis and Prognosis*
       - Ken Shackleton

1996-04 *O Teorema da Equivalência Ricardiana: aplicação à economia portuguesa*
       - Carlos Fonseca Marinheiro

1996-03 *O Teorema da Equivalência Ricardiana: discussão teórica*
       - Carlos Fonseca Marinheiro

1996-02 *As taxas de juro no MMI e a Restrição das Reservas Obrigatórias dos Bancos*
       - Fátima Assunção Sol e José Alberto Soares da Fonseca

1996-01 *Uma Análise de Curto Prazo do Consumo, do Produto e dos Salários*
       - João Sousa Andrade