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Residential water demand under block rates – a Portuguese case study

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Residential water demand under block rates – a Portuguese case study

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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 as 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), Monceur (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,

\[
D = p_1q_1 + \sum_{i=2}^{m} p_i(q_i - q_{i-1}) - p_m q_m
\]  

(1)

where

\( q_i \) - upper volume of consumption in the i block;

\( p_i \) - price of the consumption in the \( i^{th} \) block;

\( p_m \) – marginal price, the price of the consumption in the \( m^{th} \) 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](image)

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:

\[
BILL = \alpha + \beta q + \mu
\]  

(2)

Then, the values of \( BILL \) are regressed against corresponding \( q \) values to obtain the estimated linear \( BILL \) function. Its slope, \( \hat{\beta} = \frac{\partial BILL}{\partial q} \), 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

\[ IVD = \hat{\alpha} \]

\[ IVP = \hat{\beta} \]

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 services2 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:

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

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 $i^{th}$ 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:

\[ Bill = (CC + SC) + q_3 \times p_{ww} \]  

(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 10\(^{th}\) cubic meter of water consumed

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

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,

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$^3$ 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

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definition (unit)</th>
<th>Type</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>Water consumption of the typical family (m³)</td>
<td>CS-TS</td>
<td>8.592</td>
<td>1.9716</td>
<td>4.6361</td>
<td>15.58668</td>
</tr>
<tr>
<td><strong>Independents</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ivp</td>
<td>Instrumental variable for water (plus sewerage) marginal price (€ 1997)</td>
<td>CS-TS</td>
<td>0.688</td>
<td>0.1149</td>
<td>0.4692</td>
<td>0.9062</td>
</tr>
<tr>
<td>Ivd</td>
<td>Instrumental variable for difference variable(€1997)</td>
<td>CS-TS</td>
<td>1.335</td>
<td>0.7411</td>
<td>0.3690</td>
<td>2.7286</td>
</tr>
<tr>
<td>Dumc</td>
<td>Dummy variable (1 if the price applies to all cubic metres; 0 otherwise)</td>
<td>CS-TS</td>
<td>0.333</td>
<td>0.4721</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Numres</td>
<td>Number of residents per household</td>
<td>CS</td>
<td>2.52</td>
<td>0.2138</td>
<td>2.2</td>
<td>2.8</td>
</tr>
<tr>
<td>ov65</td>
<td>Percentage of people over 65</td>
<td>CS</td>
<td>0.167</td>
<td>0.01913</td>
<td>0.1461</td>
<td>0.1954</td>
</tr>
<tr>
<td>Temp</td>
<td>Normal maximum monthly air temperature (ºC)</td>
<td>CS-TS</td>
<td>13.895</td>
<td>4.5297</td>
<td>3.6</td>
<td>20.9</td>
</tr>
<tr>
<td>Prec</td>
<td>Normal monthly precipitation (mm)</td>
<td>CS-TS</td>
<td>82.858</td>
<td>45.160</td>
<td>6.2</td>
<td>148.6</td>
</tr>
</tbody>
</table>

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:

\[ q_a = \beta_0 + \beta_1 ivp_a + \beta_2 ivd_a + \beta_3 dumc_a + \beta_4 inc_a + \beta_5 numres_a + \beta_6 ov65_a + \beta_7 temp_a + \beta_8 prec_a + \epsilon_a \]  \hspace{1cm} (4)

where \( i = 1, 2, \ldots, 5 \) is the index which identifies each municipality and \( t = 1, 2, \ldots, 72 \) denotes time period. \( \epsilon_a = \mu_i + \nu_a \) refers to the error term. The \( \mu_i \) component is a community specific error term, and reflects spatial unexplained variation while the \( \nu_a \) 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 \( \beta \) 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.

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\(^4\) Using the “xtregar” instruction, from the software STATA 8.0.
Table 3 – Results of the estimated residential demand equation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimated coefficient</th>
<th>Z Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>10.22722</td>
<td>3.48*</td>
</tr>
<tr>
<td>Ivp</td>
<td>-6.976089</td>
<td>-6.34*</td>
</tr>
<tr>
<td>Ivd</td>
<td>0.7730964</td>
<td>4.18*</td>
</tr>
<tr>
<td>Dumc</td>
<td>0.6718489</td>
<td>2.90*</td>
</tr>
<tr>
<td>Inc</td>
<td>-0.00046</td>
<td>-0.13</td>
</tr>
<tr>
<td>Numres</td>
<td>1.481168</td>
<td>2.60*</td>
</tr>
<tr>
<td>Ov65</td>
<td>-34.85687</td>
<td>-5.27*</td>
</tr>
<tr>
<td>Temp</td>
<td>0.1978384</td>
<td>6.01*</td>
</tr>
<tr>
<td>Prec</td>
<td>0.0046476</td>
<td>1.36</td>
</tr>
</tbody>
</table>

Adjusted $R^2$ 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. 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

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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 \textit{numres} means that where the household is large, consumption will also be high. The negative sign of the \textit{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 \textit{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.

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All errors and omissions remain the authors’ sole responsibility.


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