Price specification issues under block tariffs: a Spanish case study

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Abstract

A panel of aggregate data from Spain is used to estimate domestic water demand functions under linear and non-linear tariffs. The use of intra-annual European data constitutes an innovative contribution. The average price per unit of water sold is compared with other price specifications that have been suggested to analyze aggregate data. Average-price elasticity estimates lie between -0.51 and -0.67 and are substantially larger than marginal-price elasticity estimates. Elasticities appear inversely correlated to the size of free allowances covered by minimum charges. Climatic variables seem to affect use, although less than in wealthier and drier areas.

Keywords: Water demand; Water resources management; Water pricing.

1. Introduction

The design of a pricing policy for domestic water supply requires reasonable knowledge of the effects that alterations in the control variables bring on water use. Since tariffs can be altered by the policy maker, special attention should be paid to their effects. Many case studies contribute to the analysis of these effects by estimating water demand functions. However, most of them use US data. Empirical evidence stemming from European countries is still very scarce.

In this study, the residential water demand function in the northwest of Spain is estimated using data aggregated at the municipal level and collected for each billing period. Differences in frequency of billing have been accounted for by transforming all data into their monthly equivalents. The use of data per billing period instead of annual data is still very rare in European studies. Different price specifications are used and the resulting estimates compared, with particular attention paid to the difference between responses to average-price versus marginal-price measures.

Unlike most previous European studies which look at only linear or simple two-part tariffs, this paper also analyzes block tariffs. Additionally, many of the sampled towns use water tariffs that include a
minimum charge whereby a certain minimum volume of water must be paid for, regardless of whether
it has been consumed. This makes it possible to calculate differentiated elasticities for communities with
no minimum charge, those with a minimum charge covering a small amount of water, and those with a
minimum charge covering a large amount of water, and to compare them with the elasticities calculated
for the whole sample.

2. The estimation of water demand functions

Water demand has been extensively studied in recent years (see OECD (1999) or Arbués et al. (2003)
for a compilation of studies). However, while most studies have used USA data (Billings 1982; Schefter
& David 1985; Chicoine & Ramamurthy 1986; Nieswiadomy & Molina 1989), empirical evidence from
European countries is rather scarce. Some studies based on European data are Hanke & de Maré (1982),
Point (1993), Hansen (1996), Höglund (1999) and Nauges & Thomas (2000). However, to the author’s
knowledge, no previous study, except for Martínez-Espiñeira (2003), which used a larger sample for the
same area and period as the present one, has used intra-annual data from Europe1.

Under block pricing, it is difficult to choose the price specification for the demand function. Lately,
most models employ the combination of marginal price and a difference variable that represents the
income effect imposed by the tariff structure (Nordin 1976). The difference variable is the difference
between the actual total bill and what users would have paid if all units were charged at the marginal
price. When using aggregate data, however, this formulation can be applied in different fashions, the
more theoretically correct of them requiring more costly data (see Schefter & David 1985).

Conventional consumer theory assumes that users have perfect information about their preferences
and constraints. They are assumed to react to changes in marginal prices and not to changes in
intramarginal prices, because the former create a substitution effect while the latter are assumed to create
only an income effect. However, under high relative costs of information on the tariff, water users might
respond more to average price changes than to marginal price changes (Foster & Beattie 1981a, 1981b;
Nieswiadomy 1992) by obtaining information on the total bill and the total amount consumed and
roughly calculating an average price. Extra effort would be needed to learn about the marginal price.
Calculating the marginal price from a bill in the presence of pricing blocks is not easy, and calculating
which block consumers are consuming in (and therefore which marginal price they are facing) is even
more difficult. This might not be considered worthwhile, especially since the relative cost of water is
low compared to income.

It has been argued that determining which price consumers respond to is an empirical question
(Nieswiadomy & Molina 1989). Opaluch (1982, 1984) proposed a model (also developed by Chicoine
& Ramamurthy (1986)) to empirically test which price reaction is actually supported by the data
considered. Previous studies, such as Nieswiadomy & Cobb (1993), Höglund (1999) and Nauges &
Thomas (2000) have estimated demand models based on both marginal and average prices. They
normally found average price elasticity higher than marginal price elasticity.

The estimation of water demand under block tariffs poses other problems, since prices are
endogenously determined by quantity demanded. In the face of simultaneity, Instrumental Variables
estimation techniques, such as Two-Stage Least Squares (2SLS), are preferable to the most common

1 Hanke & de Maré (1982) used biannual data only.
Ordinary Least Squares (OLS) estimation. Another solution consists of creating a linear approximation to the total bill and deriving from it instrumental variables for the marginal price and the difference (Billings 1982). This is one of the specifications involving a marginal price used in this paper. However, as explained by Dinar (2000, pp. 25–26), it is dubious that, in most cases, there is an economic basis for simultaneity problems to be expected, which justifies the use of simpler but more reliable techniques based on the assumption of non-simultaneity.

Modelling the choice of consumption block is also problematic. This choice is often simply left out of the analysis and only the block where the typical consumer is located is considered. To correctly specify demand under multiple-block tariffs, a two-stage model may be used, in which first the block is selected in a discrete-choice fashion and then the quantity within that block is chosen in a continuous way. Hewitt & Hanemann (1995) and Pint (1999) are among the very few who studied water demand using these techniques. These require individual data or costly data on the distribution of consumers among blocks. They are also highly sensitive to the underlying assumptions in the form of the preference functions and the distribution of unobservable tastes. A recent promising development is the use of a non-parametric approach to estimate the demand functions (Nauges & Blundell 2002).

Multiple-block pricing and minimum charges render the analysis difficult. Not taking into account the specificity of the pricing structure can generate biases, while a whole description of the consumer choice rests heavily on the perfect information assumption. It also makes the econometric treatment more difficult and demands the use of data not commonly available to the researcher, mainly when household-level data are not available. In this paper several different approaches are employed and the results compared.

Estimating demand functions from aggregate data under block pricing, which is the case in this paper, can be problematic. The results might be biased unless the aggregate marginal price and difference variables are weighted by the, usually unobserved, proportion of households actually consuming in each rate block (Schefter & David 1985; Martínez-Espiñeira 2003). Many empirical studies resort to the marginal price and the difference value faced by the typical household. Using household level data is the theoretically preferred approach (Young 1996; Saleth & Dinar 2000). However, attempts at the micro level are rather few, since they require a great volume of costly information. A good sample of micro data is also difficult to obtain because of the characteristics of several variables included in the demand function (especially personal income). Therefore, many previous studies use aggregate data (Billings & Agthe 1980; Carver & Boland 1980; Griffin & Chang 1990; Hansen 1996; Höglund 1999; Nauges & Thomas 2000).

3. Water supply and water pricing in the northwest of Spain

The area chosen for the study comprises four Spanish Comunidades Autónomas (Galicia, Asturias, Cantabria and the Basque Country) and four water-basin agencies (Galicia-Costa and Norte I, II and III). This region, known as the Green Spain has an Atlantic climate with abundant rainfall, regularly distributed throughout the year, and which occasionally exceeds 500–600 mm (sometimes reaching even 1500 mm). Most of the rest of Spain has a much different climate, with an annual rainfall below 500–600 mm.

The population served by the water authorities in this area of almost 41,000 km² was 6293,987 in 1995, with an estimated urban water supply of about 335 litres per person per day (l/(p d) (MIMAM
Urban demand is much more relevant as a percent of total use (31\%) than in the whole of Spain (13\%). This is mainly due to the fact that irrigation, which accounts for 68\% of the demand in Spain is only behind 22\% of the water used in the northwest basins (MIMAM 2000, p 326). Official final consumption estimates (INE 2000) in the period 1996–99 range from 122 l/(p d) in Galicia to 255 l/(p d) in the Basque Country. Most of the difference between the water supplied and the water finally used has to do with network losses (ranging from 11\% in the Basque Country to 28\% in Asturias\(^2\)). According to the same survey, the level of final consumption by domestic units in Spain was 147, 154 and 159 l/(p d) in 1996, 1997 and 1998. The variable \(PCAP\) in Table 1 shows the summary figures for this concept in the actual sample used.

Water quality is very good in northwestern Spain, with over 75\% of the water quality monitoring stations in the four basins showing an excellent level of quality (MIMAM 1999, pp. 86–89). When the targets derived from EU Directive 75/440/CEE (concerning ‘the quality required of surface water intended for the abstraction of drinking water in the Member States’) are considered, the requirements to fall within the best classification are met for all the monitoring stations in the area (to be compared with only 75\% for the country as a whole).

The service is relatively reliable in the area, if compared with the south of the country. However, if the availability of resources is considered, it is surprising that supply problems still arise rather frequently during the summer season. These are solved mainly by resorting to groundwater (especially

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**Table 1. Variables summary**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Cases</th>
</tr>
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<tr>
<td>(ACC)</td>
<td>5530.8156</td>
<td>10369.7345</td>
<td>79.0000</td>
<td>129556</td>
<td>1909</td>
</tr>
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<td>(AP)</td>
<td>68.0289</td>
<td>27.6066</td>
<td>11.4514</td>
<td>139.6254</td>
<td>1909</td>
</tr>
<tr>
<td>(AP10)</td>
<td>68.1842</td>
<td>29.2204</td>
<td>16.4034</td>
<td>183.4461</td>
<td>1909</td>
</tr>
<tr>
<td>(DEN96)</td>
<td>545.0706</td>
<td>1460.9108</td>
<td>16.9000</td>
<td>16897.2000</td>
<td>1909</td>
</tr>
<tr>
<td>(FAM)</td>
<td>3.3173</td>
<td>0.4007</td>
<td>1.6047</td>
<td>4.4549</td>
<td>1909</td>
</tr>
<tr>
<td>(HI)</td>
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<td>0.1083</td>
<td>0.3438</td>
<td>0.9146</td>
<td>1909</td>
</tr>
<tr>
<td>(INC)</td>
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<td>1.3363</td>
<td>3.0000</td>
<td>8.0000</td>
<td>1909</td>
</tr>
<tr>
<td>(IVD)</td>
<td>172.7275</td>
<td>183.3055</td>
<td>173.8149</td>
<td>1027.8724</td>
<td>1909</td>
</tr>
<tr>
<td>(IVP)</td>
<td>55.3249</td>
<td>26.6491</td>
<td>9.6731</td>
<td>135.3437</td>
<td>1909</td>
</tr>
<tr>
<td>(NBL)</td>
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<td>1909</td>
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<tr>
<td>(O64)</td>
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<td>0.0480</td>
<td>0.0933</td>
<td>0.3537</td>
<td>1909</td>
</tr>
<tr>
<td>(P10)</td>
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<td>23.8020</td>
<td>12.4598</td>
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<td>1909</td>
</tr>
<tr>
<td>(PCAP)</td>
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<tr>
<td>(Q)</td>
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<td>2.5361</td>
<td>3.5481</td>
<td>19.2069</td>
<td>1909</td>
</tr>
<tr>
<td>(RDAY)</td>
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<td>1.0000</td>
<td>29.0000</td>
<td>1909</td>
</tr>
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<td>(SM)</td>
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<td>1909</td>
</tr>
<tr>
<td>(TD)</td>
<td>153.4852</td>
<td>198.2122</td>
<td>-364.2627</td>
<td>1027.8724</td>
<td>1909</td>
</tr>
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<td>(TEMP)</td>
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<td>249.0000</td>
<td>1909</td>
</tr>
<tr>
<td>(TP)</td>
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<td>23.8120</td>
<td>11.9903</td>
<td>138.9595</td>
<td>1909</td>
</tr>
<tr>
<td>(UND19)</td>
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<td>0.0339</td>
<td>0.0742</td>
<td>0.2580</td>
<td>1909</td>
</tr>
<tr>
<td>(YEAR)</td>
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<td>1.4293</td>
<td>1993</td>
<td>1998</td>
<td>1909</td>
</tr>
<tr>
<td>(Ti)</td>
<td>22.40404</td>
<td>19.19339</td>
<td>6</td>
<td>75</td>
<td>99</td>
</tr>
</tbody>
</table>

\(^2\) The estimates from Cantabria are not commented upon, since visual inspection reveals that the estimates are not reliable.
scarce in the Norte I basin) or interbasin transfers (in particular from the Ebro basin to the Norte III basin).

When it comes to the ownership and regulation of utilities, there is a distinction between resource development, transportation, purification, and distribution of water, and the collection and treatment of wastewater. Water basin agencies are responsible for developing water resources, planning and supplying water, while local municipal units are responsible for distributing water and sanitation services to urban users, independent industrial users and farmers. However, water final distribution and sewage collection is often contracted out to private companies, mixed public–private bodies or public companies (Dinar & Subramanian 1997, p. 105). In some cases, the supply is provided by a supra-municipal entity, which should facilitate the exploitation of scale economies in some parts of the service (MIMAM 2000, p. 257). There is a clear trend among larger systems towards privatized management. At the same time, sewage collection and water treatment services tend to stay under public management while abstraction, treatment, distribution, network and meters conservation, and administrative services go more readily into private or semi-private hands (see AEAS 1998, p. 23). The ownership regime of the water supply entities ends up being very diverse.

Traditionally, water tariffs in Spain have not promoted an efficient use of the resource. In many cases, tariffs are not based on economic criteria and parts of the service (in particular capital costs associated with resource development and water treatment) are implicitly subsidized (particularly where the service is supplied directly by the municipality). The entities in charge of setting the prices are often guided by political rather than economic objectives. In most cases, there is no regard to the variability of supply costs according to season. Since tariffs fail to reflect the full cost of the service, water users do not generally have an incentive to use water in an efficient manner.

The water bill is made up of a number of different items. There is a charge for water supply and a charge for water treatment, where applicable, but some other components of the bill (such as garbage fees or municipal taxes) are completely unrelated to the volume of water used. This further distorts the ability of the tariff to promote a rational use of water. Efficiency is hampered also by the fact that some urban use is still measured by communal meters.

Table 2 shows the current average level of prices in the four Comunidades Autónomas concerned. It can be seen that they are generally lower than the countrywide averages.

4. Data

Data were requested from suppliers in the northwest of Spain on tariffs for domestic water supply services (including sewage charges if applicable), total domestic registered use (and charged use when different) per billing period and number of domestic accounts. Also, if block tariffs or tariffs with minimum charges were used, the number of cubic metres sold at each price was asked for. The data were standardized into monthly equivalents, by assuming that consumption during the two-monthly, four-monthly or, most often, three-monthly period was constant, to generate a total of 1909 observations.

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3 For further details on the institutional structure of the water industry in Spain and in relation to other countries see Gistau (1997), AEAS (1998) and Porta (1998).

4 This assumption is open to criticism, but should be more acceptable than the one implicitly made by studies that use annual data, namely that the average climatic conditions and use are constant during the whole year.
These were used to construct an unbalanced panel (different communities offered data from a varying number of years between 1993 and 1999). The number of towns effectively included in the calculations was 99 and the average length of the time series finally used was 22.4 months (see variable $Ti$ in Table 1).

Most communities used a tariff including a minimum charge plus a second block charged at a single rate, or several blocks (normally two) charged at increasing rates. No tariffs were based on decreasing blocks. Linear tariffs (based on a constant price for all units sold) or linear tariffs with a minimum charge were behind almost one-third of the cases observed (see variable $NBL$ in Table 1). Data on prices were deflated, using a regional monthly varying retail index, into real 1992 Spanish Pesetas (ESP$^5$). Tariffs were transformed into their monthly equivalents so that they could be compared.

Few utilities kept records on the number of users per block, a pervasive problem in the empirical literature. This prevented the correct weighting of average marginal prices and differences, which is the appropriate procedure according to the theory (Scherter & Davis 1985). However, the data on the number of cubic metres sold at each price permitted the calculation not of a weighted marginal price and difference but of a properly weighted average price.

For each town, several sources provided the data needed to construct the sociodemographic variables. Information was also collected on meteorological data (from the closest station to each town)\(^6\).

5. Methodology

5.1 Price specifications

5.1.1. Average price. Different price specifications are compared. The first one uses the average price per cubic metre sold: $AP$. This could have been calculated as the ratio of total revenue to total use in each billing period (as in Billings & Day 1989; Nauges & Thomas 2000). However, data on revenue were not so readily available, and would have been less reliable, because water companies usually introduce accounting distortions (related, for instance, to late payments) in their records. Instead, the average price was calculated as follows:

$$AP_{it} = \left[ \sum_{k=1}^{K} (w_{kit} P_{kit}) + S_{it} \cdot FXP_{it} \right] / W_{it}$$

\(^5\) 1 ESP = 0.005 892 75 USD (August 2002); 1.00 ESP = 0.006 010 12 EUR

\(^6\) Due to space limitations, further details on the information obtained and the way it was manipulated are omitted but are available upon request. See also the description of variables in the appendix.
where \( w_{kit} \) is the number of cubic metres sold at each price \( P_{kit} \) for a number of blocks \( K \). \( S_{it} \) is the total number of users billed, \( FXP_{it} \) is the fixed component of the water bill and \( W_{it} \) is the total use of water in the period. These variables vary across \( i=1,...,N \) towns and \( t=1–T \) periods, although the price variables \( P_{kit} \) and \( F_{it} \) are (before correction for inflation) basically fixed in each year for each town, since the tariffs are normally reviewed only annually.

The variable \( AP \) is equivalent to a weighted average of the true, but here unobserved, individual average prices, where the weights are given by the proportion of water sold to each consumer. This is equivalent to the result of properly weighting (according to how representative that consumer is in terms of level of use) the individual average prices paid by each consumer. In mathematical notation this hypothetical calculation would be

\[
AP_{it} = \sum_{j=1}^{S} ap_j \frac{q_j}{\sum_{j=1}^{S} q_j}
\]

(2)

where \( ap_j \) is the (in fact, unobserved) individual average price and \( q_j \) is the volume of water use associated with each user \( j = 1, ..., S \). Equation (2) shows that \( AP \) considers and appropriately weights all the block prices and fixed quotas, not only the price of the block where the typical user (or any other predetermined level of use) falls. Therefore, under block pricing, it should perform better than the average price faced by the typical user (as in Stevens et al. 1992) or the average price associated with any other level of use (as in Griffin & Chang (1990), Point (1993) or Höglund (1999)). \( AP \) uses information on consumption in each block in each period, so its value changes every period \( t \).

5.1.2. Instrumental variables as price variables. The performance of the \( AP \) specification can be compared with those employed in other studies. One of them, labelled here \( IV \), was proposed by Billings (1982) and parts from an artificial linearization of the tariff structure from which instruments for marginal price and the Nordin (1976) difference variable are derived. It assumes that consumers, instead of taking the effort to learn how the tariff works and which block they are consuming in at each moment in time, will roughly estimate the whole tariff as a ray line given by an intercept and a constant marginal price. \( IV \) assumes a higher level of consumer information than \( AP \) above.

To create a constant marginal price and difference parameter for each rate structure, first the total bill is calculated, using only the rate schedule, for each rate structure over the range of demanded quantities found in the data set\(^7\). These values are then regressed against their associated \( W \) values (where \( W \) is the water demanded). This procedure results in the estimation, for each rate schedule, of a total bill/revenue function \( TR=\hat{a}+\hat{b}W \). This linear approximation is used to derive values of marginal price: \( dTR/dW=\hat{b}=IVP \), which is the slope of the total bill function. The intercept of the estimated linear approximation, \( \hat{a} \) (the total estimated bill when the quantity demanded is zero) is the difference between what consumers actually pay and what they would pay if all units were sold at \( IVP \). This variable, labelled \( IVD \), is the difference proposed by Nordin (1976). The values of \( IVP \) and \( IVD \) are (before inflation correction) largely fixed in each year for each town, since the tariffs are normally reviewed only annually.

Billings (1982) argues that, since \( IVP \) and \( IVD \) do not vary with observed quantities, this estimating technique avoids the systematic biases due to measuring \( W \) with error and using its values to determine individual values for marginal price and the difference variable. The values of the \( IV \) variables will not

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\(^7\) The range chosen in this study was all the integer values between 4 m\(^3\) to 33 m\(^3\).
vary with average water use but only with the tariff structure and/or levels. Therefore, the simultaneity problems attached to the use of marginal price and difference variables associated with the typical use (see Section 5.1.3) are avoided. This method was criticized by Oshfeldt (1983), who argued that it would not solve completely the errors-in-variables problem. Billings agreed with his contentions and proposed that the researcher used more than one model and compared the results on a case-by-case basis (Billings 1983).

5.1.3. Price variables for the typical consumer. The third formulation, often encountered in the early literature (Billings & Agthe 1980; Carver & Boland 1980) uses simply the marginal price and difference variable faced by the typical user (TP and TD). These variables use information on the average monthly consumption and their values change with it. However, they change in a discrete way because, due to the length of the price blocks, there needs to be a large variation in average consumption for it to surpass the current block border. This means that the TP and TD price variables should present much less variability than AP.

When deriving the AP, TYP and OP (see Section 5.1.4) measures, it was assumed that consumers falling within the volume comprised by the minimum charge perceived an implicit marginal price equal to the ratio of the minimum charge (net of FXP, if applicable) to the number of units covered by the minimum. Theoretically, the marginal price faced by those consumers is zero. The assumption is made that, for such low levels of use and bill amounts, consumers do not make the effort to calculate the true marginal price and roughly interpret the marginal price as the implicit marginal price resulting from the tariff structure. Although theoretically arbitrary, the assumption is realistic.

5.1.4. Marginal and average prices for the consumer of 10 m³. A fourth specification (OP) includes the difference between the average and the marginal price faced by the user of 10 m³ a month (OPAL) and the marginal price associated with that use (P10). These values are virtually fixed in each year for each town. This price specification is used to determine whether, and to what extent, users react to average price rather than marginal price (Opaluch 1982, 1984; Chicoine & Ramamurthy 1986).

5.2 Econometric models

The data have an unbalanced panel structure (Hsiao 1986; Greene 1993). Let i=1–N be the index identifying each municipality and t=1–Ti the time index. The equation to be estimated is assumed linear and of the type:

\[ Q_{it} = \beta X_{it} + \gamma Z_{it} + \alpha_i + \mu_{it} \]  

where \( Q_{it} \) is the dependent variable, \( X_{it} \) is a \( 1 \times K \) vector of time-varying variables and \( Z_{it} \) is a \( 1 \times G \) vector of static variables. \( \alpha_i \) is the component of variation not explained by the equation that is purely spatial. That is, any factor specific to each town not in the model is included in \( \alpha_i \), which is i.i.d. \( N(0, \sigma^2_\alpha) \) and may be correlated with parts of \( X \) and, initially, \( Z \). The component of the residual that includes non-explained variation that is both spatial and temporal, \( \mu_{it} \), is assumed uncorrelated with \( X_{it} \) and \( Z_{it} \) and is i.i.d. \( N(0, \sigma^2_\mu) \). Finally, \( b \) and \( g \) are conformably dimensioned vectors of slope coefficients associated with the time-varying and the static variables, respectively.

\(^8\) Regressions for AP with a double-log functional form are presented in Table 7.
Q is the dependent variable in all regressions. This variable is the result of the transformation of the initial data on average use per billing period (normally three months and many times only two months) into their monthly equivalents. This transformation assumes that use within billing periods is constant. The variables in X are water (plus sewage) price variables (described in Section 5.1), climate variables (TEMP and RDAY) and the size of free allowance covered by the minimum charge (SM). Z includes the sociodemographic variables family size (FAM), income (INC), percent of people over 64 (OV64) and the proportion of houses considered main residences (H1).

Equation (3) could be estimated by Ordinary Least Squares (OLS) if it were assumed that \( a_i \) is identical for every town. If the assumption was, in fact, not tenable and the residuals appeared correlated within each town, the estimations would be inefficient. Also the OLS estimator would equally weight the temporal variation and the spatial variation, independently of their relative importance in the sample. This choice against OLS was also supported by the Lagrange multiplier tests (see Greene 1993).

One possibility consists of assuming that the local effects are fixed for each town and not random. This FEE is consistent and unbiased, even if the independent variables are correlated with the spatial error. However, FEE will present efficiency problems as it does not use the information stemming from the between-group variation, which is left simply as part of the residual. Additionally, the FEE is computed by transforming observations into deviations from the town means, which eliminates all the static variables \( Z \). To circumvent this problem, the coefficients of the time-varying variables were estimated by FEE and then the coefficients of the static variables were recovered in a second step, consisting of regressing the predictions of the fixed effects on the static variables (see Hsiao 1986, p. 51; Kerkhofs & Lindeboom 1997; Martínez-Espiñeira 2002). This model is labelled DUM.

Finally, the Between-Groups estimator (BG) estimator assumes that all the variation in the dependent variable depends on the town the observations belong to and consists of estimating by OLS a model where variables have been transformed into their group averages. BG will be biased and inconsistent when \( a_i \) is correlated with the regressors.

Further details about these formulations and the tests conducted to verify their validity have been omitted but are available upon request.

6. Results

The regressions were run on the unbalanced panel of 1909 observations. The log–log form for AP was also applied to three subsamples: one with SM=0, one with the 50% remaining observations with lowest SM and one with the 50% remaining observations with highest SM (see Table 7). Only one other previous European study (Martínez-Espiñeira 2002) has explicitly modelled, for a larger sample from this same region, the influence of minimum charges.

6.1 Specifications

The Hausman tests (Hausman 1978) favor FEE over REE in all the regressions, in line with previous studies (Nauges & Thomas 2000; Martínez-Espiñeira 2002), which also suggest that the endogeneity of the price variables plays a relevant role.

The sociodemographic variables eliminated by the FEE were recovered in a second step: DUM. This method assumed that all the static variables were exogenous. This makes sense, since the variables
concerned were income, age structure, type of household and family size. It also agrees with results found elsewhere (Nauges & Thomas 2000; Martínez-Espiñeira 2002⁹).

OLS and BG results are also reported. These present problems, as explained previously, but show how BG gives more weight to the static variables than to the time-varying ones. This is to be expected in a study of monthly water use, since the climate and price variables explain a greater part of the within variation of use than the underlying sociodemographic variables. The BG estimation would resemble more the results obtained using annual data.

The goodness of fit in the different models is close to 0.70 (adjusted $R^2$). The DUM regressions tend to explain between one-third and one-half of the remaining variation.

6.2 Price variables: elasticities

Elasticities vary continuously along the linear demand curves, so reported values were calculated at the average price and average use. The FEE of the AP coefficient yields an elasticity of around -0.51 (see Table 3). The elasticity with respect to IVP (Table 4) is about -0.18 and, with respect to TP, is about -0.12 (Table 5). These values are close to the values found by Hanke & de Maré (1982) and Höglund (1999) for other European areas.

As usual (Nieswiadomy 1992; Nieswiadomy & Cobb 1993; Billings & Day 1989; Höglund 1999), average price elasticity is found much higher than marginal price elasticity. It is normally assumed that the average price elasticity, even though reflecting better the consumers’ imperfect perception of the tariff, overestimates their response to price changes. In this analysis both price elasticities are found within reasonable values, suggesting that they could be regarded as the upper and lower bounds for the true elasticity.

In principle, the TP-TD specification is expected to yield an underestimation of the price elasticity and an overestimation of the elasticity with respect to the difference variable. IVP and IVD are not the totally theoretically correct variables either, unless consumers do perceive the tariff as a ray line, exactly as defined for their calculation. However, the comparison between the results for IV and for TYP (Table 5) shows small differences, although the elasticity with respect to IVP does present a bigger size (-0.18) than for TP (-0.12).

When the OP price formulation is employed to check whether consumers react more to an approximation to the average price than to the marginal price, Table 6 shows that the marginal price ($P10$) elasticity is non-significant but positive. However, it cannot be rejected that the coefficients for $P10$ and OPAL are equal, which confirms that consumers seem to react more to average price than to marginal price. This result has been found elsewhere (Billings & Day 1989; Nieswiadomy & Cobb 1993; Nauges & Thomas 2000).

When deriving the price variables, it was assumed that the marginal price for volumetric units covered by the minimum charge was equal to the minimum charge divided by the number of units covered by this charge. This assumption proves valid now and partly explains why general use is more a function of average price than a function of marginal price. Again, the OP specification is not the theoretical way of introducing the price specification recommended by Nordin (1976) and commonly agreed upon in the

---

⁹ This study used a larger sample for the same area and period and formally tested the exogeneity of the same variables used here.
literature. However, the results of the Opaluch tests suggest that consideration be given at the price elasticities found for the AP specification.

Since AP includes only positive values (as opposed to the difference variables) a logarithmic functional form can be used (Table 7). This implies a constant price elasticity and embodies the realistic feature of a non-null level of consumption for even infinitely high prices. However, it also assumes no intercept for the direct demand curve, and, therefore a satiation level of water use at infinitely low prices only (which is not all that realistic).

Table 7 summarizes the FEE results when this functional form is employed. It was applied on four samples. First a complete sample (2113 observations), for which a constant price elasticity of

The second row shows t ratios: significant at *=10%; **= 5%; ***=1%. FEE includes only the time-varying variables. The Hausman test (Hausman 1978) compares FEE and REE for those varying variables. DUM is the regression of the dummies predictions (from FEE) on the static variables. The first step of DUM uses more observations than FEE, because it does not need information on sociodemographics. Elasticities are reported at the weighted means of price and quantity.

10 Although it avoids simultaneity problems suffered by the TYP specification.

11 A larger sample than before was used, including 204 extra observations for which no sociodemographic information was available, since FEE would not need it.
about -0.67 was found. Then the sample was divided into three subsamples. One included the 806 observations with positive but smaller allowances covered by the minimum charge, SM. The estimated price elasticity for this sample was -0.55. A second subsample includes the 806 observations with larger SM (price elasticity of -0.38). The last subsample included the 500 observations not affected by minimum charges. For this last sample the elasticity was much larger than for any other sample, rising up to a value of -1.26. It is likely that efficiency problems affected the estimation on this reduced sample, but it still illustrates how minimum charges weaken the reaction of consumers to price.

The coefficients of the difference variable (for IVD and TD) are highly significant and present a negative sign (showing that water is a normal good). In most cases (about 90% in the 1909 sample), the difference variable takes positive values even though most towns use increasing block tariffs. This is due to the counteracting effect of high minima and/or fixed quotas, which works against water conservation, distorting the pro-conservation incentive pursued by the increasing tariff. This can also be shown by the results of the double-log estimations for AP (Table 7). These show that, for subsamples where the free allowances included in the minimum charge are null or small, the elasticity is much larger and the goodness of fit of the model is higher.

Table 4. Total sample. Specification IV. Average: Q (dependent) = 10.597915; IVP = 62.654352

<table>
<thead>
<tr>
<th>Model</th>
<th>OLS</th>
<th>BG</th>
<th>FEE</th>
<th>DUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVD</td>
<td>-0.032974</td>
<td>-0.0026865</td>
<td>-0.0093846</td>
<td></td>
</tr>
<tr>
<td>IVP</td>
<td>-0.0358133</td>
<td>-0.0325247</td>
<td>-0.0296683</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-14.958***</td>
<td>-4.155***</td>
<td>-6.118***</td>
<td></td>
</tr>
<tr>
<td>RDAY</td>
<td>-0.0271333</td>
<td>-0.2433044</td>
<td>-0.0182220</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-3.080***</td>
<td>-1.209</td>
<td>-2.799***</td>
<td></td>
</tr>
<tr>
<td>TEMP</td>
<td>0.0025611</td>
<td>-0.0690898</td>
<td>0.0049967</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.373**</td>
<td>-4.294***</td>
<td>6.207***</td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>0.1940298</td>
<td>0.0987243</td>
<td>0.1732297</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18.360***</td>
<td>2.677***</td>
<td>5.237***</td>
<td></td>
</tr>
<tr>
<td>FRQ</td>
<td>-0.0428323</td>
<td>-0.1037866</td>
<td>-0.1596268</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.582</td>
<td>-0.442</td>
<td>-0.306</td>
<td></td>
</tr>
<tr>
<td>FAM</td>
<td>-0.0849710</td>
<td>0.7174204</td>
<td>0.2844778</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.457</td>
<td>1.285</td>
<td>0.412</td>
<td></td>
</tr>
<tr>
<td>INC</td>
<td>0.7823676</td>
<td>0.7717122</td>
<td>1.0421860</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17.131***</td>
<td>4.363***</td>
<td>4.427***</td>
<td></td>
</tr>
<tr>
<td>OV64</td>
<td>-11.8896772</td>
<td>-11.0142397</td>
<td>-7.9699141</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-7.883***</td>
<td>-2.503**</td>
<td>-1.486</td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>3.3152098</td>
<td>4.8066730</td>
<td>3.3871547</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.734***</td>
<td>2.822***</td>
<td>1.499</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>7.6042247</td>
<td>18.1080866</td>
<td>5.1415165</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.463***</td>
<td>4.070***</td>
<td>1.414</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>1909</td>
<td>99</td>
<td>1909</td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.397</td>
<td>0.604</td>
<td>0.678</td>
<td></td>
</tr>
<tr>
<td>Hausman test</td>
<td>61.01</td>
<td>61.01</td>
<td>61.01</td>
<td></td>
</tr>
<tr>
<td>Price elasticity</td>
<td>-0.212</td>
<td>-0.192</td>
<td>-0.175</td>
<td></td>
</tr>
</tbody>
</table>

See notes for Table 3.
6.3 Billing variables

Dandy et al. (1997) explicitly studied the effects of free allowances with an Australian sample. However, the analysis of the effect of SM constitutes an innovative exercise in the European literature. It is expected that monthly use be positively affected by SM, since there is no incentive to economize water until the minimum threshold is crossed. The results confirm these intuitions, since the sign for SM is significantly positive in all equations (except for the subsamples in Table 7, where the results for SM are rather poor due to its obvious lack of variation). These results confirm that free allowances provide a disincentive to the conservation of the resource. As described in the previous subsection, the results of the double-log estimations for AP (Table 7) show that, for null or small free allowances included in the minimum charge, the price elasticity is higher, adding to the evidence that large free allowances counteract the conservation effects of price-based measures.

The use of these minimum charges can be explained by both economic and political reasons. First, the supply of a free-at-the-margin\textsuperscript{12} amount of water for basic needs could be justified, since this water

\textsuperscript{12} Or charged at any other price below marginal cost.
Table 6. Total sample. Specification OP. Average: $Q$ (dependent) = 10.597915; $P10$ = 59.925296

<table>
<thead>
<tr>
<th>Model</th>
<th>OLS</th>
<th>BG</th>
<th>FEE</th>
<th>DUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPAL</td>
<td>-0.0312852</td>
<td>-0.0284351</td>
<td>-0.0752795</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-13.247***</td>
<td>-4.100***</td>
<td>-5.785***</td>
<td></td>
</tr>
<tr>
<td>P10</td>
<td>-0.0319582</td>
<td>-0.0236011</td>
<td>0.0020668</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-11.677***</td>
<td>-2.685***</td>
<td>0.240</td>
<td></td>
</tr>
<tr>
<td>RDAY</td>
<td>-0.0268207</td>
<td>-0.2682901</td>
<td>-0.0163251</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-2.991***</td>
<td>-1.291</td>
<td>-2.453**</td>
<td></td>
</tr>
<tr>
<td>TEMP</td>
<td>0.0023341</td>
<td>-0.0743223</td>
<td>0.0048941</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.123***</td>
<td>-4.452***</td>
<td>5.940***</td>
<td></td>
</tr>
<tr>
<td>SM</td>
<td>0.1712159</td>
<td>0.0804319</td>
<td>0.0930034</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.321***</td>
<td>2.083**</td>
<td>1.946*</td>
<td></td>
</tr>
<tr>
<td>FRQ</td>
<td>-0.1549400</td>
<td>-0.2856876</td>
<td>-0.1135657</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-2.351**</td>
<td>-1.409</td>
<td>-0.213</td>
<td></td>
</tr>
<tr>
<td>FAM</td>
<td>-0.0869247</td>
<td>0.7349558</td>
<td>0.2996549</td>
<td>0.413</td>
</tr>
<tr>
<td></td>
<td>-0.457</td>
<td>1.284</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INC</td>
<td>0.7490718</td>
<td>0.7566949</td>
<td>1.2129615</td>
<td>4.900***</td>
</tr>
<tr>
<td></td>
<td>16.181***</td>
<td>4.170***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OV64</td>
<td>-9.6177320</td>
<td>-8.809967</td>
<td>-8.1907085</td>
<td>-1.453</td>
</tr>
<tr>
<td></td>
<td>-6.337***</td>
<td>-1.982**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>3.3066081</td>
<td>4.1013604</td>
<td>3.7027122</td>
<td>1.559</td>
</tr>
<tr>
<td></td>
<td>5.084***</td>
<td>2.164**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>7.6682960</td>
<td>19.6790341</td>
<td>-0.3664325</td>
<td>-0.996</td>
</tr>
<tr>
<td></td>
<td>6.365***</td>
<td>4.170***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>1909</td>
<td>99</td>
<td>2113/99</td>
<td>0.373</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.375</td>
<td>0.584</td>
<td>0.664</td>
<td>1909</td>
</tr>
<tr>
<td>Hausman test</td>
<td>3.3066081</td>
<td>4.1013604</td>
<td>3.7027122</td>
<td>1.559</td>
</tr>
<tr>
<td>Price elasticity</td>
<td>-0.181</td>
<td>-0.133</td>
<td>0.012</td>
<td></td>
</tr>
</tbody>
</table>

See notes for Table 3.

Table 7. Log models. Dependent variable: $\text{LOG}(Q)$

<table>
<thead>
<tr>
<th>Model sample</th>
<th>FEE (all)</th>
<th>FEE (small SM)</th>
<th>FEE (large SM)</th>
<th>FEE (no SM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{LOG}(AP)$</td>
<td>-0.6680251</td>
<td>-0.5581169</td>
<td>-0.3726723</td>
<td>-1.2617759</td>
</tr>
<tr>
<td></td>
<td>-17.403***</td>
<td>-10.377***</td>
<td>-6.093***</td>
<td>-16.200***</td>
</tr>
<tr>
<td>$\text{LOG}(RDAY)$</td>
<td>-0.0331736</td>
<td>-0.0113976</td>
<td>-0.0424100</td>
<td>-0.0208943</td>
</tr>
<tr>
<td></td>
<td>-4.822***</td>
<td>-1.476</td>
<td>-4.138***</td>
<td>-0.988</td>
</tr>
<tr>
<td>$\text{LOG}(TEMP)$</td>
<td>0.0609949</td>
<td>0.1165461</td>
<td>0.1996636</td>
<td>-0.0145418</td>
</tr>
<tr>
<td></td>
<td>6.607***</td>
<td>9.432***</td>
<td>10.938***</td>
<td>-0.858</td>
</tr>
<tr>
<td>$\text{LOG}(SM)$</td>
<td>0.0157364</td>
<td>-0.0013114</td>
<td>-0.0263143</td>
<td>-0.863***</td>
</tr>
<tr>
<td></td>
<td>7.507***</td>
<td>-0.331</td>
<td>-8.863***</td>
<td>-1.262</td>
</tr>
<tr>
<td>$N$</td>
<td>2113</td>
<td>806</td>
<td>806</td>
<td>500</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.760</td>
<td>0.852</td>
<td>0.659</td>
<td>0.770</td>
</tr>
<tr>
<td>Hausman test</td>
<td>179.0</td>
<td>28.71</td>
<td>12.42</td>
<td>16.65</td>
</tr>
<tr>
<td>Price elasticity</td>
<td>-0.668</td>
<td>-0.558</td>
<td>-0.373</td>
<td>-1.262</td>
</tr>
</tbody>
</table>

The sample is larger than above because no sociodemographic variables need be used and extra observations on time-varying variables were available. The Hausman test for the sample of larger SM suggests $\text{REE}$ as the best model. It yields a elasticity of $-0.399$. There is not enough variation for $\text{FRQ}$ to be used.
usage would be generating external benefits. In the area analyzed, this justification provides little support for the large volumes supplied at a null marginal price, because users can afford what most would regard as water for essential uses (drinking, cooking and basic personal hygiene). In this sense, the first part of the recommendation in Chapter 18 of the Agenda 21 Declaration:

‘In developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems. Beyond these requirements, however, water users should be charged appropriately’ (UNCSD 1992)

would have limited relevance. It would not, in any case, account for the large values of SM found in the sample.

Second, if only wealthier households were assumed to consume over SM m³ of water a month, a redistributive argument would support their use too. It is debatable that a simplistic relationship can be established between water use and household income. A careful study of the redistributive impact of minimum charges in relation to other pricing structures would be needed to draw conclusions on this issue. This would analyze the relationships between household size, water use and income. Van Humbeeck (2000) conducted this type of analysis for the case of the Flanders part of Belgium, where, precisely with the aim of improving the redistributive impact of water prices, a free allowance per person (not per account) is now granted.

Finally, a minimum charge smooths the revenue stream of the water utility and helps it cover its fixed costs. This applies most of all where the municipality expects private capital to invest in infrastructure, because the investors will want to recover in a guaranteed way a fraction of their fixed costs.

Lack of variability of the billing frequency (FRQ) resulted in normally non-significant estimates, although they were always negative. This suggests, although in an inconclusive manner, that more frequent billing might promote conservation, probably due to an enhanced-information effect.

6.4 Climate variables

One of the contributions of this research to the European literature on water demand relates to the monthly variation of the variables analyzed. This permits a more interesting approach to the analysis of the effects of climate on water use. The coefficients of RDAY and TEMP are not too large, but are highly significant. The small size of the estimated coefficients suggests that climate effects do not play a great role. This agrees with a priori expectations and previous results (Martínez-Espiñeira 2002) that suggest that the role of outdoor use in this region is not as important as in other areas with drier and warmer climates, more tourism and higher income per capita. The results obtained here for northwestern Spain could well be close to those expected for other similar areas of Europe. However, comparisons can so far be made only against the much less significant results found by using annual data.

6.5 Sociodemographic variables

The analysis of the sociodemographic variables does not present as conclusive results as the ones above. This is because of the difference in variability between the dependent variable and the
sociodemographic variables in Z. Problems of multicolinearity between some variables have been detected too.

FAM presents the expected positive sign. This means that, in towns where the average family is larger, consumption will also be higher, although less than proportionately so. However, as Tables 3–6 show, the size of the estimates seems to be underestimating the influence of extra members of the average family on average household water consumption. In fact, it cannot be rejected that the coefficient is null. INC shows a positive sign in all cases and its estimate is highly significant. Since water bills account for a small proportion of available family income, income should not affect water demand significantly. However, households with higher incomes and, probably to a larger extent, households in richer communities, should be expected to consume many of the commodities complementary to water use and therefore, indirectly, use more water. As expected, OV64 has a negative sign, although it is not highly significant. A higher proportion of people over 64 can be expected to result in lower average use of water (see also Nauges & Thomas 2000).

An innovative variable in this paper is H1. The expectation would be a positive sign: towns where most houses are used only during holidays or weekends should present a lower average use. The estimations do suggest a positive effect (the estimates being highly significant for the OLS and BG regressions, although not for the DUM), confirming the expectations.

7. Conclusions and policy implications

The results agree with those obtained by the vast majority of previous case studies elsewhere. Domestic water demand appears to be inelastic but not perfectly inelastic. Results for both marginal and average price elasticities fall within the ranges of those found in the literature, most of all if European case studies are considered. Within current price ranges, the values estimated for price elasticities suggest that the scope of pricing policies by themselves to rationalize the use of water, at least in the short term, might be rather limited. On the other hand, pricing policies based on the full-cost recovery principle might not be politically feasible after years of subsidized prices.

Average price seems to outperform marginal price as a determinant of household use, although average price elasticities appear to somewhat overestimate consumers’ responses. This adds support to the choice of less theoretically appealing variables based on the assumption of low levels of user information over theoretically valid variables based on costly information when aggregate data are analyzed. This would particularly be the case in areas where the water bill includes a series of components that further distort the ability of the consumer to relate the size of the bill to the volume of water used and water bills are a small proportion of household income. Higher prices might result in increased levels of consumer information, and perhaps higher levels of elasticity (even if they would drive consumption towards more essential uses).

One characteristic of the area studied is the use of minimum charges. The study confirms that this structure works against the conservation of the resource by increasing water use. The results reveal not only that the larger the size of the minimum the higher the average use but also that price elasticities are higher when this size is smaller. Since water amounts covered by the minimum charge are sold at a marginal null price while probably being provided at a positive marginal cost, inefficiencies are likely to occur.

The climate variables exert a significant effect on water use, although it appears that the use of
swimming pools and the watering of gardens is not as relevant as in other drier, warmer and wealthier areas. On the other hand, the elasticities estimated for this area of Spain, where water prices are relatively low, suggest that lower elasticities might be expected in Northern Europe. This is because consumers in those areas, where higher prices are charged, are probably consuming in less elastic ranges of their demand curves.

In summary, it can be concluded that water pricing can help rationalize water use in the area, although it might need to be combined with other demand-management measures. This might include information campaigns, efforts to link the size of the water bill to the actual level of use and information about the level of use of different home appliances. It is to be expected that likely substantial increases in prices, a consequence of either the current trend towards the privatization of parts of the supply service or an attempt to implement full-cost recovery measures, will drive consumers towards different ranges of their demand curves. These might exhibit eventually higher or lower levels of elasticity, but short-run reactions to price would probably be weak. This means that increased prices, resulting in much higher bills, might generate political resistance, at least initially.

However, the results must be regarded with caution. Given the nature of the data-collection process, the study is subject to the effect of problems of measurement, recording and processing errors. The analysis presented here implies accepting that this method of studying water demand does not offer definite answers. Nevertheless, the findings of this study support others that recommend a demand-management over a supply-augmentation approach to water resources management. They also provide a guide to the regulator or the private water industry managers in designing water pricing schemes.

Acknowledgements

I gratefully acknowledge the financial support of ESRC (UK) and valuable comments by Jack Pezzey, Charles Perrings, Keith Hartley, Céline Nauges and two anonymous referees. All remaining errors are my sole responsibility.

Appendix

Variables definition

These variables have been mentioned in the text. Further details about their calculation and the way the data were obtained are available upon request.

\[ \text{ACC} \quad \text{total number of domestic accounts in each period.} \]
\[ \text{AP} \quad \text{average price per cubic metre sold (1992 ESP). Calculated as:} \]
\[ \text{AP} = \frac{\sum (PR_N \cdot P_N \cdot Q) + FXP}{Q} \]  \hspace{1cm} (A1)\]
\[ \text{AP10} \quad \text{average price paid by a 10 m}^3 \text{ user (1992 ESP/m}^3). \]
\[ \text{FAM} \quad \text{average number of members of the household.} \]
FXP fixed component of water + sewage bill. It does not include the amount paid for the units of consumption covered by the minimum charge\(^{13}\) (1992 ESP).

FRQ number of billing periods a year.

HI \% of dwellings statistically regarded as main residence.

INC index for estimated family disposable income per capita in the municipality. Unit = interval labels: 1–8.

IVD similar to IVP for the Nordin difference variable (1992 ESP).

IVP instrumental marginal price variable estimated from a linear regression of the theoretical water bills as explained in Section 5.1 (1992 ESP/m\(^3\)).

NBL binary variable: 1 if the tariff is linear or linear with a minimum charge and 0 otherwise (if there are increasing blocks).

OPAL calculated as \(AP_{10} - P_{10}\) (1992 ESP/m\(^3\)).

OV64 \% of population over 64 at 1/5/96 (%).

\(P_{10}\) marginal price associated with a 10 m\(^3\) use (1992 ESP/m\(^3\)).

PCAP per capita use, calculated from MONTHLY and FAM (l/(p d)).

\(P_N\) (water + sewage) price of the units sold within each block \(N\) (block 1 normally coincides with the minimum charged). VAT is added and the provincial variations of the RPI (INE 1999) are used to deflate values. Unit = 1992 ESP/m\(^3\).

\(PR_N\) \% of m\(^3\) charged at \(PBL_N\).

\(Q\) monthly equivalent average use per account (m\(^3\)/month).

RDAY number of days with precipitation in the month.

SM number of units charged regardless of actual use (m\(^3\)/month).

TD Nordin difference faced by an average or typical user. It is the difference between what the typical user pays minus what he would have paid had all units been charged at \(TP\) (1992 ESP).

TEMP average temperature in each month (ºC/10).

\(TP\) marginal price associated with \(Q\) use, that is, the marginal price faced by the average or typical consumer (1992 ESP/m\(^3\)).

References


\(^{13}\) The fixed quota affects the whole range of consumption, while the fixed-quota effect of the minimum charge ceases beyond the minimum threshold.


