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Working Paper - 01/10

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Henrique Monteiro*

Abstract

The increasing popularity of increasing block tariffs (IBT) for water is reflected in Portugal by a virtually universal implementation for residential use. IBT are often supported as a good tool for achieving the goals of equity, water conservation and revenue neutrality but seldom have they been grounded on efficiency justifications. We test the conditions derived by Roseta-Palma and Monteiro (2008) for IBT to be a second-best pricing practice under water scarcity and budget balancing constraints, when consumers are heterogeneous and the fixed charge is only allowed to cover fixed costs. Because, in these conditions, the choice of tariff schedule design is dependent on the price-elasticity of demand and the way it varies with consumption levels, we estimate the Portuguese residential water demand and show that the resulting recommended tariff schedule hinges crucially on the choice of functional form. After the proper specification test, a choice between a semilogarithmic lin-log and a double-log specifications is left undecided, which does not prove the superiority of IBT, but also does not enable its dismissal. Besides the usual determinants found in the prolific residential water demand estimation literature we find that the proportion of seasonally inhabited dwellings and a reduced water quality on delivery can have a significant negative influence on the amount of water households consume.

JEL classification: C23; C52; D42; Q21; Q25

Keywords: water pricing; residential water demand; increasing block tariffs; choice of functional form; water quality.

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1 Introduction[1]

Increasing block tariffs (IBT) are often supported as a good tool for achieving the goals of equity and water conservation (Bithas (2008)). The lower prices charged for the first cubic meters of water are meant to favour the consumers with lower incomes, using water mainly for essential uses such as drinking, washing, bathing or flushing a toilet. The higher prices for the following consumption blocks are set to induce water savings from more intensive water users, usually associated with wealthier households and with nonessential uses such as sprinkling gardens or filling pools. It is thus seen as a form of cross-subsidization of the access to an essential good by the poorer through the penalization of wasteful consumptions of the richer. A third objective to be achieved through IBT is revenue neutrality (Baumann, Boland and Hanemann (1997)) because they allow the utility to break-even, while still using marginal-cost pricing for the upper blocks, in a situation of increasing marginal costs[2]. If Ramsey pricing is used, no particular block rate will necessary equal marginal cost, but the prices for consumption units will come as close to the optimum solution as allowed by the budget-balancing restriction[3]. One last justification for IBT is the presence of a positive externality from a minimum amount of water consumption from a public health point of view, "reducing the risks of communicable diseases throughout the community" (Boland and Whittington (2000)). Cardadeiro (2005) develops the argument that, up to a level of satisfaction of basic human needs, a positive public health externality exists and derives the formal implications for an optimal water tariff, which, in his proposal, should include two increasing rate blocks.

In spite of the growing popularity of IBT both in developed countries (OECD

[1]This paper was created within the research project POCI 2010/EGE/61306/2004–Tarifaqua, supported by the FCT - POCI 2010, co-financed by the European fund ERDF. The author thanks the valuable comments from José Passos and Catarina Roseta Palma. Any errors or omissions are the authors' own responsibility.

[2]The water industry is usually seen as a natural monopoly, with large fixed costs and decreasing average costs. Nevertheless, if we consider the opportunity costs of using water resources in situations of scarcity, marginal costs will be increasing, and may in theory overcome average costs, making them increasing from that point onward.

[3]IBT may result from Ramsey pricing under certain conditions, but this is not a necessity. Uniform rates or decreasing block tariffs can also be a result of a Ramsey pricing technique.

(2009), OECD (2006) and OECD (2003)) and in the developing world (Boland and Whittington (2000)) they are also subject to criticism. Sibly (2006) argues that "IBT are inferior to two-part tariffs" concerning efficiency and that equity goals could alternatively be achieved through the service charge. Boland and Whittington (2000) also show the limitations of IBT, proposing instead that a rebate be coupled with a uniform volumetric rate, for the purpose of achieving a balanced budget for the water utility. Hewitt (2000) also points out that IBT induce greater variability in the utilities' revenues, especially if a great proportion of users is consuming in the upper blocks and the variable component of the tariff is significant relative to the fixed charge.

Even the equity argument for IBT has been subject to some criticism, especially regarding its application in the developing world. The existence of shared connections and indirect purchasing of water from neighbors is pointed out by Whittington (1992) and Boland and Whittington (2000) as a reality which may lead the poor to pay a higher price for water if IBT are in place. The same argument has been used regarding households with numerous members, more frequently associated with low income families (Dahan and Nisan (2007) and Bithas (2008))[4]. Crase, O'Keefe and Burston (2007) sums up the merits and disadvantages of IBT while Baumann et al. (1997) presents some case studies of their application.

Hewitt (2000), p. 275 notes that "utilities are more likely to voluntarily adopt this market mimicking rate structure [IBT] if they are located in climates characterized by some combination of hot, dry, sunny, and lengthy growing season", something that is confirmed by the recent OECD publications (OECD (2009), OECD (2006), OECD (2003)). In Europe they are more common in the Mediterranean countries like Portugal, Spain, Italy, Greece or Turkey, where the majority of the utilities adopts them[5]. This also happens in Japan and

[4] See Barberán and Arbués (2009) for an example of a water tariff design proposal which takes into account the household size in order to improve equity with increasing block tariffs. The same concerns with the introduction of equity criteria in the design of residential water tariffs are reflected in the proposals of García-Valiñas (2005*a*) for two-part tariffs and Ramsey pricing and in the proposal of Diakité, Semenov and Thomas (2009) for a nonlinear social price. Schoengold and Zilberman (2009) discuss the conditions under which block tariffs can simultaneously achieve the goals of efficiency, revenue neutrality and equity.

[5] See OECD (2003), pp. 72-3, table 3.4, OECD (2006), pp. 32-3, table 5 and OECD (2009), pp. 100-1, annex 3.A2.

South Korea, which are located at a similar latitude. They are also common in countries like Belgium and the USA and Australia but to a less extent. In Portugal, IBT are commonly used by water utilities to price residential water use. Their presence is virtually universal, even though the tariffs are decided at the level of each of the more than 300 municipalities, as shown by Monteiro and Roseta-Palma (2007). The National Regulating Authority for Water and Waste has included a four-block tariff design in its proposal for a tariff regime that should seek to promote efficient water pricing, as imposed by the European Water Framework Directive, approved in 2000 and translated into the new Portuguese Water Law in 2005.

Roseta-Palma and Monteiro (2008) have shown that nonlinear increasing tariffs may be justified as a second-best optimum in a situation of water scarcity and budget-balancing requirements when the water utility faces heterogeneous consumers[6]. The conditions under which nonlinear increasing tariffs may be justified by efficiency reasons as a second-best solution were derived. In this paper we aim to test whether those conditions hold in Portugal and whether the climate can be a justification for the adoption of IBT. The answer to this question depends on the characteristics of the water demand function, namely the behavior of its price-elasticity. Therefore, we provide empirical estimations for residential water demand.

Households can be seen as heterogeneous consumers with different characteristics and preferences. For example, the indoor water demand has been proven to differ from the outdoor/sprinkling water demand[7]. The behavior of households regarding water use will therefore be different, depending on whether they live in an apartment or in a detached house with a swimming pool or a garden. Families also differ in the amount of water-using appliances[8] or water saving

[6] A two-part tariff could be a first-best optimum, but its efficiency may be limited when the flexibility to use the fixed charge to balance the utilities' budgets is restricted. This is the case in Portugal, where Law 12/2008 (AR (2008)) implies that charging a fixed fee must be reasonably justified. This has been interpreted as a need to associate the revenues from the fixed charge with the fixed costs of the service, which, if coupled with marginal cost pricing, may be insufficient for a balanced budget if marginal costs are not constant.

[7] Several studies find that price-elasticity of water demand is lower for indoor than for outdoor water uses, for example: -0.23 (indoor) -1.6 to -0.7 (outdoor) (Howe and Jr (1967)); -0.305 (indoor) and -1.38 (outdoor) (Danielson (1979)); -0.07 (indoor) and -0.68 (outdoor) (Mansur and Olmstead (2007)).

[8] Ford and Ziegler (1981) incorporates the number of water using appliances in his estima-

devices[9] they have at home, in the number of persons in the household or in their income. While the former are characteristics which can be translated into discrete variables, the latter varies in a continuous fashion. Although discrete customer heterogeneity may also be interpreted in association with the different customer classes (residential, commercial, industrial, agricultural), we will focus on residential water demand, for which there is better available data.

Not only is water demand estimation important to allow us to test IBT efficiency conditions, but it is also valuable in itself to water managers, as growing scarcity shifts the focus from supply increasing policies to demand management tools like water pricing[10]. Knowing consumers' behavior is essential for the implementation of such demand side management policies (Agthe, Billings and Buras (2003)). It is thus "desirable to estimate water demand" given the "serious role that water demand plays in scarcity, policy and project analysis, markets and pricing" (Griffin (2006), p.273). In the words of Renzetti (2002), "for the person who is reading this book on a hot, sunny day, there is little need to explain the importance of water and the value of understanding the relationship between water use and economic influences" (ibid., p.1) (he then proceeds to present some justifications in the introduction to his book on water demand for all other readers).

We present the efficiency conditions for IBT in section 2 and show the impact that the choice of functional form can have on their empirical testing in section 3. In section 4 we briefly review the residential water demand literature and section 5 describes the model to be estimated as well as the data. Section 6 explains the methodology, estimates the model and interprets the results, while in section 7 the proper specification tests are performed. Section 8 concludes.

tion of residential water demand at the household leve, while Garcia and Reynaud (2004), Nauges and Reynaud (2001) and Nauges and Thomas (2000) are examples of the incorporation of these kind of concerns in studies with aggregate data through the use of variables such as the % of households equiped with bathtubs or toilets.

[9] Yoo (2007) incorporates dummy variables for the existence of water saving devices in his study of residential water demand.

[10] Martin and Kulakowski (1991), for whom "knowing that there is an inverse relantionship between price and quantity demanded, and that price-elasticity of demand is inelastic rather than elastic, is all that is required" is a notable exception disagreeing with the need to obtain precise price-elasticity estimates. Nevertheless, at least one of the authors did find himself engaged in the activity he later finds unnecessary (Martin and Thomas (1986), Martin, Ingram, Lancy and Griffin (1984)).

2 An efficiency justification for increasing block tariffs

Roseta-Palma and Monteiro (2008) have derived the consequences for the water tariff design from using a second-best Ramsey pricing method (i.e., with a budget balancing constraint) in a situation of water scarcity and heterogeneous consumers. In particular they derived the necessary and sufficient condition for increasing, constant and decreasing nonlinear pricing to be the most efficient solution while respecting all constraints.[11] The optimal pricing rule, shown here as equation (1) is the classical inverse elasticity rule from Ramsey pricing, where p_m is marginal price, C is total cost and w^* is the optimal water consumption. The additional unusual component $\mu/(1+\lambda)$ results from the introduction of resource scarcity (μ is the Lagrangian multiplier of the water scarcity constraint and λ is the one from the balanced budget constraint) and reflects the opportunity cost of consuming water. Marginal water supply costs are not only a function of water consumption, but also of weather factors. They decrease with greater levels of rainfall and increase with higher temperatures (ϕ denotes hotter and drier weather conditions). Naturally, weather also affects demand. Consumer heterogeneity is represented by θ, which can stand for continuous characteristics like income or discrete features like household size or other household attributes (owning a pool, living in a detached house, water using appliances, number of taps and so on).

$$\frac{p_m - \left(\dfrac{\partial C\left(w^*, \phi\right)}{\partial w^*} + \dfrac{\mu}{1+\lambda} \right)}{p_m} = \frac{\lambda}{1+\lambda} \frac{1}{\xi(w^*, \theta, \phi)} \tag{1}$$

In the inverse-elasticity rule, the mark-up of the price over the marginal cost is inversely correlated with the absolute value of the price-elasticity of demand ($\xi(w^*, \theta, \phi)$). This implies that higher prices must be charged to customers with more rigid demands. The tariff structure schedule will depend on the result

[11] We did not include fixed costs in the model nor did they consider the possibility of using the fixed component of the tariff as a tool to guarantee that the utility breaks even. We implicitly considered that the fixed charge is calculated so as to cover exactly the fixed costs of the water supply activity, which is a situation similar to what is recognized as legally admissible in Portugal, since the publication of Law 12/2008 (AR (2008)).

of the following necessary and sufficient conditions[12], where B stands for the monetized benefit function:

$$\frac{\dfrac{\partial B}{\partial w^*}\left[\dfrac{\partial^3 B}{\partial w^{*3}}w^* + \dfrac{\partial^2 B}{\partial w^{*2}}\right]}{\left[\dfrac{\partial^2 B}{\partial w^{*2}}\right]^2 w^*} < 1 \Leftrightarrow \text{ Increasing block tariffs} \tag{2}$$

$$\frac{\dfrac{\partial B}{\partial w^*}\left[\dfrac{\partial^3 B}{\partial w^{*3}}w^* + \dfrac{\partial^2 B}{\partial w^{*2}}\right]}{\left[\dfrac{\partial^2 B}{\partial w^{*2}}\right]^2 w^*} = 1 \Leftrightarrow \text{ Uniform rates} \tag{3}$$

$$\frac{\dfrac{\partial B}{\partial w^*}\left[\dfrac{\partial^3 B}{\partial w^{*3}}w^* + \dfrac{\partial^2 B}{\partial w^{*2}}\right]}{\left[\dfrac{\partial^2 B}{\partial w^{*2}}\right]^2 w^*} > 1 \Leftrightarrow \text{ Decreasing block tariffs} \tag{4}$$

Moreover, $\dfrac{\partial^3 B}{\partial w^{*3}} \leq 0$ is a sufficient condition for IBT to be an efficient solution.

Roseta-Palma and Monteiro (2008) also derive the conditions for which the implementation of IBT is preferred for drier and hotter climates. The following set of conditions, if combined, are sufficient for IBT adoption to increase with temperature levels and lower amounts of precipitation:

$$\frac{\partial^3 B}{\partial w^{*3}} \leq 0 \Leftrightarrow \frac{\partial^2 p}{\partial w^{*2}} \leq 0 \tag{5}$$

$$\frac{\partial^3 B}{\partial w^{*2}\partial \phi} \geq 0 \Leftrightarrow \frac{\partial^2 p}{\partial w^{*}\partial \phi} \geq 0 \tag{6}$$

$$\frac{\partial^4 B}{\partial w^{*3}\partial \phi} \leq 0 \Leftrightarrow \frac{\partial^3 p}{\partial w^{*2}\partial \phi} \leq 0 \tag{7}$$

Condition (5) requires the water demand function to be concave. For (6) to apply the slope of the inverse demand function must not become more steep with temperature increases (or lower precipitation levels). Finally, (7) implies that the function's concavity could not decrease for higher levels of temperature

[12] In the text we refer to increasing block tariffs and decreasing block tariffs, which are "real-world" tariff schedules. Because the model from Roseta-Palma and Monteiro (2008) is derived in a continuous fashion, the conditions apply strictly to continuously increasing, uniform or decreasing nonlinear tariffs and not to block rates. Nevertheless, we use the conditions to discuss the efficiency in the increasing or decreasing nature of the "real-world" tariffs, so we choose to use the more familiar terms.

and drier conditions. Taken together they denote a situation where warmer and more arid conditions have a greater impact on high levels of consumption and where the willingness to pay for water rises more significantly under these circumstances, which can be understood if we consider the association of larger users with households with greater incomes (whose water expenses weigh less on their budget) and probably houses with pools or gardens.

It should be noted that, since the verification of the above conditions at the optimum point of consumption is sufficient, they will also apply if they can be verified for the entire range of the demand function. Our econometric estimation of water demand will aim to check whether these theoretical conditions hold for the Portuguese case.

3 The importance of the choice of functional form

Given the findings in the previous literature, which we review in section 4, the water demand function can be written as:

$$w = w\left(p, \theta, \phi, z\right) \tag{8}$$

where w is the quantity of water demanded and p is the water price. As was previously mentioned, θ stands for income and ϕ represents weather variables such as temperature and precipitation. The vector z can include other household attibutes related to water consumption like garden or household size, the age and education of the household members or the number of water using appliances, just to name a few. $w\left(\ldots\right)$ is a parametric function which usually takes one of the functional forms we now describe.

The choice of the functional form for the equation to be estimated is one of the important decisions to be taken by the empirical analyst. Five types of functional forms are more commonly used in the estimation of residential water demand: linear, double-log; semilogarithmic (lin-log or log-lin) and Stone-Geary. The choice of one of these options is not neutral and can have an impact on the results. Espey, Espey and Shaw (1997) and Dalhuisen, Florax, de Groot and Nijkamp (2003) include a dummy variable for loglinear specifications in their meta-analysis of the price-elasticities of water demand estimated in the literature and find positive coefficients, meaning that, *ceteris paribus*, a loglinear specification may result in a less elastic estimate. This fact is known to empirical researchers, despite the fact that it has received less attention than other aspects of the estimation process like the choice of the estimation technique (Renzetti (2002)). In this section we evaluate the consequences of different functional forms for the verification of the previous conditions for IBT.

3.1 Linear specification

Linear functions are common in water demand estimation, although more so in the early years than in recent studies. A linear demand function has the following form:

$$w = ap + b\theta + c\phi + dz' + f \tag{9}$$

where a, b, c, d and f are parameters to be estimated. The corresponding inverted demand function is:

$$p = \frac{w - (b\theta + c\phi + dz' + f)}{a} \tag{10}$$

With this kind of functional form, not only is the sufficient condition for IBT (condition (5)) automatically verified, but that is also the case for conditions (6) and (7). This was expected because linear functions impose that demand is more elastic for higher levels of price (lower consumption levels) and lower otherwise. In linear demand functions, absolute values of the price-elasticity of demand decrease with the quantity demanded, generating IBT when coupled with the inverse elasticity rule from (1).

3.2 Double-log specification

Even more popular than the linear specification is the logarithmic functional form or double-log[13]. Double-log demand specifications assume a constant price-elasticity for every price level which can be read directly from the estimated

[13] This can be seen from the two meta analysis performed by Espey et al. (1997) and Dalhuisen et al. (2003) where the majority of the studies used logarithmic functional forms.

coefficient for price. The double-log functional form for water demand can be written in the following fashion:

$$\ln w = a \ln p + b \ln \theta + c \ln \phi + dz' + f \tag{11}$$

The corresponding inverted demand function is:

$$p = \exp \left\{ \frac{\ln w - (b \ln \theta + c \ln \phi + dz' + f)}{a} \right\} \tag{12}$$

Condition (5) is verified in this case if and only if $a \geq 1$, but this implies a nonnegative slope for the demand function, which would be an unrealistic assumption. Therefore, unlike in the linear case, (5) will never be verified for a reasonable demand function with a double-log functional form. However, this does not mean that double-log specifications exclude the possibility of IBT, since we can use the necessary and sufficient condition (2) to determine the shape of the price schedule. Finally, the verification of conditions (6) and (7) would simply require a positive coefficient for ϕ.

3.3 Semilogarithmic specification (log-lin)

The semilogarithmic specification is much less frequent in the residential water demand estimation literature, but from Andrews and Gibbs (1975) to Arbués and Villanúa (2006), we do find some studies which include estimations with this functional form. The log-lin specification for water demand is:

$$\ln w = ap + b\theta + c\phi + dz' + f \tag{13}$$

The corresponding inverted water demand function is:

$$p = \frac{\ln w - (b\theta + c\phi + dz' + f)}{a} \tag{14}$$

The verification of (5) for a log-lin specification would only occur if and only if $a \geq 0$, which is a situation similar to the one found for the double-log form, i.e., the verification of the sufficient condition for IBT would imply a nondecreasing slope for the demand function, and can thus be discarded as unrealistic[14]. Although conditions (6) and (7) are automatically verified for the

[14] The same qualification applies here that this is an unconclusive case and not a dismissal of IBT and that we must always check 2 for a definitive conclusion.

log-lin form, the positive effect of temperature on the adoption of IBT would be proven from the simultaneous verification of all three conditions, which is impossible with the usual negative sloping demand function[15].

3.4 Semilogarithmic specification (lin-log)

The lin-log semilogarithmic specification is rare and is usually only estimated for comparison purposes together with other functional forms. Al-Qunaibet and Johnston (1985) and Mu, Whittington and Briscoe (1990) are two examples of its implementation. The lin-log functional form for water demand is:

$$w = a \ln p + b \ln \theta + c \ln \phi + dz' + f \tag{15}$$

The corresponding inverted water demand function is:

$$p = \exp \left\{ \frac{w - (b \ln \theta + c \ln \phi + dz' + f)}{a} \right\} \tag{16}$$

With this functional form condition (5) is never verified, not even in unrealistic conditions. The inverted water demand function is always strictly convex. The other two conditions would imply a nonnegative value for c and an opposite sign for a if c is positive, but this becomes irrelevant given the first result. Although not dismissing entirely the possibility of IBT, this functional form does not enable the verification of the above sufficient conditions for IBT.

3.5 Stone-Geary demand function and reciprocal functions in general

The Stone-Geary demand specification is:

$$w = (1 - g)\, h + g \frac{\theta}{p} + c\phi + dz' + f \tag{17}$$

The parameter g can be interpreted as the fixed proportion of the supernumerary income[16] spent on water. This specification was first applied to water

[15] Roseta-Palma and Monteiro (2008) also derive relatively more complex necessary and sufficient conditions for hotter and drier conditions to favour the adoption of IBT. We choose not to replicate them here.

[16] Supernumerary income is defined as the income remaining after the minimum amounts of water and all other goods have been purchased (Martínez-Espiñeira and Nauges (2004)). This minimum amounts are unresponsive to the respective price and are usually termed subsistence levels. The simplified version of (17) results from assuming a zero subsistence level for the other goods. See Gaudin, Griffin and Sickles (2001) or Martínez-Espiñeira and Nauges (2004) for more details.

demand estimation by Al-Qunaibet and Johnston (1985)[17].The corresponding inverted demand function becomes:

$$p = \frac{g\theta}{w - [(1-g)\,h + c\phi + dz' + f]} \tag{18}$$

We can see that the Stone-Geary is a particular form of the reciprocal demand function, where $f^* = (1-g)\,h$, $a = g\theta$ and $b = 0$:

$$w = a\frac{1}{p} + b\theta + c\phi + dz' + f^* \tag{19}$$

In fact, the conclusions are indeed the same for both forms. Because water consumption must not be less than the subsistence level implied by $(1-a)\,b + c\phi + dz' + f$, the verification of (5) will only happen if and only if $a = 0$. But this would mean that water consumption was unresponsive to price and income, contradicting economic theory and a great deal of accumulated empirical evidence. Thus the estimation of a significative Stone-Geary functional form (or any kind of reciprocal form), if considered superior to other functional forms by the relevant statistical tests, implies that we can not prove the sufficient condition for IBT.[18]

3.6 Summary of implications of the choice of functional form on elasticities of demand

We have shown that the choice of functional form can have a significant impact on the conclusions about which tariff schedule design is more adequate when facing water scarcity and budget balancing restrictions by looking at the sufficient conditions derived by Roseta-Palma and Monteiro (2008) about the shape of the demand function. Summing up, so far we have seen that while for the linear functional form the conditions for IBT are automatically verified and hotter and drier climatic conditions favour the adoption of IBT[19], for the other usual

[17] García-Valiñas, Nauges and Reynaud (2009) and Schleich (2009) are examples of recent applications.

[18] (6) would be verified if $c \leq 0$, which is unrealistic, while (7) implies that a and c must have opposite signs or that both should be null.

[19] Especially if the fixed charge is not allowed the flexibility of a lump sum charge when the utility is faced with the obligation to exactly breakeven, in a world of scarce water and consumers with heterogeneous preferences

functional forms, we must resort to (2) to know with certainty what would be the most efficient tariff schedule.

Nevertheless, from the inverse elasticity rule we know that a necessary and sufficient condition for IBT is that demand becomes less price-elastic with higher levels of water consumption. We can look directly at the influence of the assumptions imposed by each functional form on the behavior of the price-elasticity of demand. We review these consequences in this section. Tables 1 and 2 present the price and income-elasticities for the functional forms described above. We can see from 1 that demand becomes less elastic (price-elasticity becomes less negative) with higher consumption for most functional forms. Only the double-log case is associated with constant elasticities (which makes up most of its appeal) and the Stone-Geary specification has an undetermined result, dependent on the actual values of the variables and the parameters associated. For all the cases except these two, under the conditions of the Roseta-Palma and Monteiro (2008) model, IBT will be a natural consequence of demand characteristics. The next step is to estimate the water demand and test which case fits best.

Table 1: Price-elasticities of demand for several functional forms

Functional form	**Price-elasticity** $\left(\xi_p = \frac{\partial w}{\partial p}\frac{p}{w}\right)$	$\frac{\partial \xi_p}{\partial w}$
Linear	$a\frac{p}{w} = 1 - \frac{\left(b\theta + c\phi + dz' + f\right)}{w}$	>0
Double-log	a	=0
Semilogarithmic (log-lin)	$ap = \ln w - (b\theta + c\phi + dz' + f)$	>0
Semilogarithmic (lin-log)	$\frac{a}{w}$	>0
Stone-Geary	$-\frac{g\theta}{wp} = -1 + \frac{\left[(1-g)h + c\phi + dz' + f\right]}{w}$	undetermined

Note:
$a < 0$
$b, c, g > 0$
$b\theta + c\phi + dz' + f > 0$
$\ln w - \left(b\theta + c\phi + dz' + f\right) > 0$

Table 2: Income-elasticities of demand for several functional forms

Functional form	**Income-elasticity** $\left(\xi_\theta = \frac{\partial w}{\partial \theta}\frac{\theta}{w}\right)$
Linear	$\frac{b\theta}{w}$
Double-log	b
Semilogarithmic (log-lin)	$b\theta$
Semilogarithmic (lin-log)	$\frac{b}{w}$
Stone-Geary	$\frac{g}{p} = \frac{w - \left[(1-g)h + c\phi + dz' + f\right]}{\theta}$

Note:
$a < 0$
$b, c, g > 0$
$b\theta + c\phi + dz' + f > 0$
$\ln w - \left(b\theta + c\phi + dz' + f\right) > 0$

4 Literature review

The field of residential water demand has been very productive in the past decades, ever since Metcalf (1926) took on the task of studying the effects of water rates on per capita water consumption. The number of published studies in the field has risen to a three digit figure, as can be seen from Appendix A. The existence of literature surveys can be very useful to guide new research or someone just trying to figure out what have we come to know about the role that price and demand-side management policies may play in promoting an efficient use of an ever scarcer resource. Earlier studies are best covered by Boland, Dziegielewski, Baumann and Optiz (1984), but other literature reviews can be found in Hanemann (1997), Gómez-Ramos and Garrido-Colmenero (1998), Renzetti (2002), Arbués, García-Valiñas and Martínez-Espiñeira (2003) and Worthington and Hoffman (2008). Another, more quantitative source of information of the knowledge accumulated so far are the two meta-analysis of the determinants of price-elasticity of demand performed by Espey et al. (1997) and Dalhuisen et al. (2003). In Appendix A we provide an extensive, but not exhaustive, listing of the residential water demand studies in the literature and of their main characteristics.

Until the 1980's estimations for the USA dominated the literature, but since the 1990's and especially after the turn of the century, a great number of estimations from other parts of the world have been published, especially from Europe, although estimations from the developing world have already warranted a specific literature review by Nauges and Whittington (2008). For Portugal two previous estimations can be found in Martins and Fortunato (2005*b*) and Martins and Fortunato (2007).

The first few research efforts relied mostly on annual cross-section data for water utilities and on limited information on the water tariffs (having access to the unit price for a specific consumption amount instead of the entire rate schedule, for example). Nowadays, the improvement of information available enables the inclusion of a time-series dimension (and the study of seasonal variations, from monthly data) and the use of panel data is common. There is also a growing number of studies using household level data.

Water demand estimation differs fundamentally from other statistically supported water use studies in that a price variable is included as a determinant for water consumption. Throughout the years, marginal price has for the most part replaced average price as the specification of choice, but either because of data availability concerns or because the researcher believes that the price specification is an empirical question, due to the fact that consumers may not have full information on the rate schedule, average price specifications are still used or tested against marginal price[20]. The consideration of sewer charges when they appear coupled with the water price is consensual. When marginal price is the variable of choice and block rates are in place, the Taylor-Nordin specification, introduced in the water demand literature by Billings and Agthe (1980), is commonly used. It results from a modification by Nordin (1976) of the original proposal made by Taylor (1975) for a variable to accommodate the virtual income change resulting from the block design of the tariff. It considers a second price-related variable, the "difference" between the actual water bill and the value of the tariff, had all volume been charged at the marginal price. Griffin, Martin and Wade (1981) and Griffin and Martin (1981) were the first to point out the problem of the simultaneous determination of water demand and the price-related variables in the presence of block rates. It is since considered good practice to check for this bias in the estimation and, if present and significant, to solve it through instrumental variable techniques.

[20] Ruijs, Zimmermann and Berg (2008) is a recent example.

Other variables typically included as water demand determinants are the household income (or the assessed property value as a proxy in micro level studies), weather related variables such as temperature and precipitation, or alternatively lawn moisture requirements or the number of rainy/dry or hot days, and the household size (especially at the micro level). The remaining variables included differ somewhat more, sometimes reflecting specific research questions. We can find variables related to the age of the household members or the house itself, to the water using appliances, lot/garden size, population density, home ownership (Nieswiadomy (1992)), pool ownership (Dandy, Nguyen and Davies (1997)), water saving devices (Renwick and Archibald (1998) and Yoo (2007)) or even ethnic origin (Griffin and Chang (1990) and Griffin and Chang (1991)). Dummy variables in particular have been used extensively for season/month, region/city, water restrictions (Grafton and Kompas (2007)) or water conservation programs/messages (Renwick and Green (2000), Gaudin (2006) and Martínez-Espiñeira (2007)).

The functional form most widely used is the double-log specification for its convenience for the calculation of elasticities. The linear form has also been widely used, while other alternatives like the semilogarithmic or Stone-Geary approaches are rarer as we have seen in section 3.

The estimation technique is probably the most widely discussed issue, after the specification of the price-related variables. While earlier studies relied heavily on ordinary least squares, the endogeneity criticism soon stimulated the adoption of instrumental variable techniques (2SLS or 3SLS). Other methods have been used like maximum likelihood estimation, specific time-series techniques[21] or simultaneous equations methods, but it is the use of panel data techniques (fixed effects, random effects, GMM) that has seen the larger increase in the last decade. The use of discrete/continuous choice models in situations were block rates apply[22] merits special attention, but researchers have rarely had access to the necessarily more demanding information required to apply them in household level studies (Hewitt and Hanemann (1995), Olmstead, Hanemann and Stavins (2007), Olmstead (2009)) or with aggregate data (Martínez-Espiñeira

[21] The work of Martínez-Espiñeira (2007) with cointegration is a recent example.

[22] Modelling the discrete choice of block and the continuous choice of the consumption level.

(2003) and Diakité et al. (2009)).

5 The model and the data

Data on water consumption and water and wastewater tariffs was provided by the Portuguese National Water Institute (INAG) for the years 1998, 2000, 2002 and 2005. It consists of aggregate data for the 278 municipalities in mainland Portugal. It has been combined with information on the income, weather, water quality and household characteristics respectively from the Ministry of Finance and Public Administration, the National Weather Institute (Instituto de Meteorologia, I.P.), the Regulating Authority for Water and Waste Services (ERSAR, ex-IRAR) and the National Statistics Institute (INE). Due to the presence of missing data concerning consumption levels it constitutes an unbalanced panel for the study period. The missing data problem was minimized through direct collection of additional information on consumption and tariffs from the water and wastewater utilities of each municipality.

The estimated model is:

$$\begin{aligned} consumption_{it} = \; & f(mptotal_{it}, diftotal_{it}, income_{it}, prec_{it}, temp_{it}, \\ & waterqual_{it}, bathroom_i, elder_i, seasonal\_dwelling_i) + \alpha_i + \varepsilon_{it} \end{aligned} \tag{20}$$

$$\alpha_i \sim IID\left(0, \sigma_\alpha^2\right), \qquad \varepsilon_{it} = \varepsilon_{it-1} + v_{it}, \qquad v_{it} \sim IID\left(0, \sigma_v^2\right) \tag{21}$$

In (20), w is replaced by *consumption* and the price related variables (p) are $mptotal$ and $diftotal$. θ is repesented by *income*, while the weather related variables (ϕ) are *prec* and *temp*. *waterqual*, *bathroom*, *elder* and *seasonal_dwelling* correspond to the z vector of variables in model (8). This simbology correspondence is established to enable the use of Stata outputs in the following sections.

The formulation of the error variable as the sum of a municipality effect and an autoregressive component is not assumed from the outset but is instead the result of the preliminary analysis described in the next section. Tables 3 and 4[23] show the definition of the main variables used[24] and some summary statistics.

[23] The variables *waterqual*, *bathroom*, *elder* and *waterqual* are used in estimation as ratios varying from 0 to 1.

[24] Other variables were included in early larger models, but were dropped due to the in-

Table 3: Definition of variables

Variable	Definition
consumption	Average monthly water consumption (m3/month)
mptotal	Marginal price of water supply and sewage (€/m3)
diftotal	Variable part of the water and sewage bill - (MP*Water) (€/month)
fixedtotal	Fixed part of the water and sewage bill (€/month)
Income	Per capita available income (€10^3/person/year)
prec	Total annual precipitation (mm)
temp	Average annual temperature (^{o}C)
waterqual	% of delivered water analysis failing to comply with mandatory parameters
bathroom	% of regularly inhabited dwellings without shower or bathtub
elder	% of population with 65 or more years of age
seasonal_dwelling	% of dwellings with seasonal use

Table 4: Summary statistics

Variable	N	Mean	Std. Dev.	Min.	Max.
consumption	884	7.46	2.21	2.46	19.50
mptotal	871	0.62	0.39	0.05	4.59
diftotal	875	-0.73	1.24	-14.35	2.50
fixedtotal	864	2.09	1.35	0.00	10.49
Income	1112	3.48	3.27	0.67	29.80
prec	1112	877.53	435.65	205.47	2807.75
temp	1112	15.27	1.34	10.93	18.15
waterqual	1106	4.06	4.40	0.00	40.09
bathroom	1112	9.75	5.54	7.91	33.76
elder	1112	20.83	6.33	7.52	42.02
seasonal_dwelling	1112	23.98	11.13	4.54	54.10

The *consumption* dependent variable used is average monthly residential water consumption per customer[25] in cubic meters. Because virtually all water utilities adopt IBT we use the Taylor-Nordin specification with a marginal price (*mptotal*) coupled with the "difference" variable between the value of the water and sewage bill and the value it would reach had the marginal price been charged for all the volume consumed. Schefter and David (1985) point out that the correct definition of the marginal price and difference variables for aggregate

significance of the coefficients estimated or to avoid high levels of multicolinearity in the final model. Examples of variables tested and dropped are average household size, % of population served by water supply and drainage systems or wastewater treatment plants, frequency of billing, educational level attained, population density, house age or % of detached houses in total buildings.

[25] The database has an annual periodicity, from which average monthly figures are derived.

studies would be the average value of the household level of such variables and not their level at the average consumption level for the aggregate. However, very few studies had available the necessary information about the proportion of users in each block of the tariff structure to apply the theoretical correct definition and weight the averages of marginal price and difference, despite the fact that the Taylor-Nordin specification is widely accepted and used. Corral, Fisher and Hatch (1999) and Martínez-Espiñeira (2003) are notable exceptions. In our contacts with the water utilities, such information was explicitly asked for, but in the end less than a third were able to retrieve the information from their databases or records. Even among those whose management and billing software programs enabled the access to the % of users in each block, we found very few of them who could provide it systematically for the 4 years of study. Therefore, we join the mass of researchers using the best possible methods given the available data, when more theoretically correct ones are unpractical.

Generally, in the presence of IBT, the difference variable is nonpositive[26] and so is its expected coefficient. However, Martins and Fortunato (2007) estimates a positive coefficient and finds a justification in the fact that the difference variable includes both the effect of the block schedule (nonpositive for IBT) and the positive fixed charge. The latter, not only renders the average price decreasing for the first cubic meters of consumption but also partially cancels out the usual effect of the block schedule. In contrast, we assume fixed charges ($fixedtotal$) are made explicit in the water bill, since they are present in virtually all residential tariffs, so that we can separate them from the "difference" variable for the volumetric part of the tariff ($diftotal$).

The *income* variable chosen is disposable income per household (deducting the personal income taxes collected from the taxable personal income) in €10^3/year[27]. The available weather related variables are total annual precipita-

[26] This is the case for the Portuguese water supply tariffs. In our estimation we add the relevant charge for wastewater drainage and treatment to the price variables to come up with the prices that the consumer actually faces in the water bill. Because it is not uncommon to find fixed charges per block of consumption (fixed within the block, but varying between blocks) in wastewater tariffs, the sewage component of the "difference" variable may be positive for volumes other than the block limits even with IBT. This effect can also be seen from the tariffs for Manila, Phillipines, shown in Palencia (1988).

[27] All monetary variables are expressed in 2005 constant prices. We used the deflator for Portuguese GDP at market prices, unit Euro/ECU, supplied by AMECO – Annual Macro-

tion (*prec*, in mm) and average annual temperature (*temp*, in ^{o}C). A measure of the quality of water delivered to the consumers (*waterqual*) is given by the % of failures to comply with mandatory quality parameters in the analysis performed by ERSAR (ex-IRAR). We expect a negative association between this variable and water consumption. Ford and Ziegler (1981) were the first to introduce a measure of perceived water quality as an explanatory factor for residential water demand. In spite of the several studies trying to estimate the willingness to pay for improved tap water quality (Whitehead (1995) and Um, Kwak and Kim (2002)) or improved service quality (Hensher, Shore and Train (2005) and Wang, Xie and Li (2008)) we found no other examples of the introduction of water quality as a regressor in water demand estimations before Piper (2003) who introduced water hardness as a measure of delivered water quality which can be perceived by the consumers. Two other recent studies use quality measures but pertaining to raw water. Reynaud, Renzetti and Villeneuve (2005) uses average biochemical oxygen demand (BOD) of raw water and Reynaud (2008) includes the share of rivers classified as having a bad quality within a given local community as regressors in water demand estimation.

The remaining conditioning variables, collected from INE, are the % of the population with 65 or more years of age in the municipality, % of inhabited residential dwellings without a shower or bathtub installed and the % of houses with a seasonal use. We expect negative coefficients for these variables.

The % of elderly people has been used as a determinant of water demand by Nauges and Thomas (2000), Nauges and Reynaud (2001), Martínez-Espiñeira (2002), Martínez-Espiñeira (2003) and Martins and Fortunato (2007). They all have convincingly shown that older people use less water. The results are not so clear when the variable used is average household age as is the case with Ford and Ziegler (1981) and Schleich and Hillenbrand (2007) which suggests that water savings are more related to elderly retired people than to age in general[28].

economic Database of Directorate General for Economic and Financial Affairs (DG ECFIN) of the European Commission).

[28] Yoo (2007) uses the number rather than the proportion of elderly people, what explains the positive coefficient obtained.

The importance of the existence of water using equipment on the amount of water demanded is recognized in many estimation studies which deal with household data through the inclusion of variables like the number of taps (Ford and Ziegler (1981) and Renwick and Archibald (1998)) or the number of bathrooms (Chicoine, Deller and Ramamurthy (1986) and Olmstead et al. (2007) are just two examples). Recently, aggregate studies have began to use their the % of houses with bathtubs and/or toilets to take this dimension into account (see, for example: Nauges and Thomas (2000), Nauges and Reynaud (2001) or Garcia and Reynaud (2004)).

Seasonality in water demand was an early concern and was considered either through the separation of indoor and outdoor/sprinkling water demands (Howe and Jr (1967)) or through the inclusion of seasonal dummy variables (Morgan (1974)). Nevertheless, its relation with a seasonal population and not only with the seasonal behavior of a stable population has failed to be considered. The exclusion of this dimension may bias the results, especially in aggregate demand studies including areas with a great importance of tourism, with a large proportion of emigrated population or with an important proportion of secondary houses owned by people living in large nearby urban centres which use the secondary house in weekends for example. This is the case in many areas of Portugal. Algarve, for example greatly increases its population in the summer with tourists from all over the country and from abroad filling up hotels and occupying rented or secondary houses, which are usually left empty for the rest of the year (a phenomenon which happens also in some other coastal areas with pleasant beaches although in a less intensive fashion). The rural villages in the inland regions also increase their population in the summer through the inflow of families with relatives who migrated to the urban centres or to foreign countries. The usual procedure of dividing total volumes of water supplied by the number of residential customers, used in aggregate studies, without consideration of this reality, where it is important, creates the usual econometric problem of relevant variables exclusion bias. The only other study known to the author which took these considerations into account was Reynaud (2008) which considered not only a dummy variable for the tourist areas but also the share of seasonal population through the inclusion of the ratio between the number of hotel rooms and camping places and the total population. He finds a positive effect of this latter variable on peak average daily residential water demand per user and surprisingly the coefficient's sign remains the same in the off-peak demand equation [29].

6 Methodology, estimation and results for a linear functional form

The problem of endogeneity of marginal price (or average price) and the difference variable in the presence of block rates, due to the fact that they are simultaneously determined with the volume consumed, has been acknowledged since the famous comments of Griffin et al. (1981) and Griffin and Martin (1981) on the estimations by Foster and Beattie (1979) and Billings and Agthe (1980). Special importance has been given to the existence of measurement error in the quantity variable and its influence on the block price assigned to observations close to the block limits. Billings (1982) eventually reestimated the model with the data set from Billings and Agthe (1980) while introducing instrumental variable techniques in water demand estimation to correct the bias. His approach consisted of regressing the total water bill resulting from specific consumption levels against those values for consumption and obtaining the instrumented variable for price from the slope of the total bill function and the instrumented variable for difference from its intercept for each rate schedule. This procedure, also followed by Agthe and Billings (1997), Martínez-Espiñeira (2002), Martínez-Espiñeira and Nauges (2004) and Martins and Fortunato (2007), for example, has been criticized by Deller, Chicoine and Ramamurthy (1986) for not solving the original measurement error problem, even if simultaneity in marginal price and difference is eliminated. They also point out that if the consumer is responding to the total water bill and not to the full information from the rate schedule the causality direction is inverted in the auxiliary regression. In the end, this technique is not really helpful in our case given that, with some excep-

[29] Only the latter variable is included in the final estimations for peak and off-peak demand.

tions of municipalities which did not update their tariffs in specific years, every data point is a specific tariff schedule in our database. Therefore, we adopt a procedure closer to Deller et al. (1986), Reynaud et al. (2005), Olmstead (2007) and Ruijs et al. (2008) and instrument the endogenous variables from exact information from the water bill. Namely we choose the marginal price corresponding to specific volumes of consumption[30] and other characteristics relevant to the calculation of the final water bill as regressors for the auxiliary equations for *mptotal* and *diftotal*.

$$mptotal_{it} = \beta_1 + \beta_2 privcompany_{it} + \beta_3 munservices_{it} + \beta_4 muncompany_{it} + \beta_5 m3\_5_{it} + \tag{22}$$

$$+\beta_6 m3\_10_{it} + \beta_7 m3\_15_{it} + \beta_8 calc\_tariff_{it} + \alpha_i + \varepsilon_{it}$$

$$diftotal_{it} = \gamma_1 + \gamma_2 m3\_1_{it} + \gamma_3 m3\_10_{it} + \gamma_4 m3\_20_{it} + \gamma_5 calc\_tariff_{it} + \alpha_i + \varepsilon_{it} \tag{23}$$

$$\alpha_i \sim IID\left(0, \sigma_\alpha^2\right), \qquad \varepsilon_{it} \sim IID\left(0, \sigma_\varepsilon^2\right) \tag{24}$$

Tables 5 and 6 present the definition and summary statistics of the variables used to instrument *mptotal* and *diftotal*.[31]

The equations (22) and (23) were estimated by a random effects model[32]. The results are presented in Figures 1 and 2.

We implement a test of exogeneity by Davidson and MacKinnon (1993) and adapted to a panel data context by Christopher Baum and Steven Sillman, through the *dmexogxt* procedure in Stata (Baum and Stillman (1999)), to confirm the endogeneity of *mptotal* and *diftotal* and the need to use instrumental variables. Results are presented in Figures 3 and 4. The small p-values of the test confirm the need to create instrumental variables for these two endogenous

[30] The specific volumes chosen resulted from previous analysis of instrument relevance and validity performed with the Anderson, Sargan and difference in Sargan tests for the values $1m^3$, $5m^3$, $10m^3$, $15m^3$, $20m^3$, $25m^3$. Figures 5 and 6 show the results of the first two tests for the final specification.

[31] The fact that maximum values for the consecutive marginal prices do not have a monotonous increasing order in spite of the wide spread use of IBT is due to the different processes used to calculate the final tariff. Most water utilities charge each m^3 of water at the price where it belongs. However, some charge the price of the last block reached for all the volume consumed, generating high values for marginal prices at the lower block limits (a graphical representation of this effect can be seen from Monteiro and Roseta-Palma (2007)). This is the reason why $calc\_tariff$ becomes essential for the creation of instruments for *mptotal* and *diftotal*.

[32] All estimations were performed in STATA version 9.2.

Table 5: Definition of the variables used to instrument mptotal and diftotal

Variable	Definition
privcompany	dummy variable (=1 if the water supply utility is a private company)
munservices	dummy variable (=1 if the water supply utility is an autonomous municipal service)
muncompany	dummy variable (=1 if the water supply utility is a municipal company)
m3_1	Marginal price of water supply and sewage for a consumption of 1 cubic meter
m3_5	Marginal price of water supply and sewage for a consumption of 5 cubic meters
m3_10	Marginal price of water supply and sewage for a consumption of 10 cubic meters
m3_15	Marginal price of water supply and sewage for a consumption of 15 cubic meters
m3_20	Marginal price of water supply and sewage for a consumption of 20 cubic meters
calc_tariff	dummy variable (=1 if all water is charged at the price of the last block reached)

Table 6: Summary statistics of the variables used to instrument mptotal and diftotal

Variable	N	Mean	Std. Dev.	Min.	Max.
privcompany	1112	0.04	0.20	0.00	1.00
munservices	1112	0.14	0.35	0.00	1.00
muncompany	1112	0.02	0.15	0.00	1.00
m3_1	1090	0.33	0.19	0.00	1.69
m3_5	1091	0.35	0.16	0.00	1.80
m3_10	1091	0.53	0.24	0.00	1.99
m3_15	1091	0.75	0.45	0.00	5.17
m3_20	1091	0.96	0.48	0.00	4.82
calc_tariff	1090	0.21	0.41	0.00	1.00

regressors. This result is confirmed by the usual Hausman test. The Hausman test statistic for the comparison of the models with and without instrumenting for *mptotal* and $diftotal$ has the value of 147.11, which corresponds to a p-value of 0.0000 in a $\chi^2(8)$. The test clearly rejects the null hypothesis of exogenous regressors in the original model and the instrumenting technique is called for.

Figure 1: Random effects regression for *mptotal*

```
Random-effects GLS regression                   Number of obs      =       871
Group variable (i): mun_number                  Number of groups   =       271

R-sq:  within  = 0.0746                         Obs per group: min =         1
       between = 0.6096                                        avg =       3.2
       overall = 0.5012                                        max =         4

Random effects u_i ~ Gaussian                   Wald chi2(7)       =    456.57
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
     mptotal |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 privcompany |   .2744924   .0651976     4.21   0.000     .1467075    .4022773
 munservices |   .2340429   .0414613     5.64   0.000     .1527803    .3153055
  muncompany |   .2767612   .0687727     4.02   0.000     .1419691    .4115533
        m3_5 |   .2332474    .090815     2.57   0.010     .0552533    .4112416
       m3_10 |   .4790264   .0780023     6.14   0.000     .3261447     .631908
       m3_15 |   .2151268   .0373536     5.76   0.000     .1419151    .2883385
 calc_tariff |   .0687644   .0295666     2.33   0.020      .010815    .1267138
       _cons |   .0493945    .033396     1.48   0.139    -.0160605    .1148495
-------------+----------------------------------------------------------------
     sigma_u |  .18935664
     sigma_e |  .20611133
         rho |  .45770915   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Figure 2: Random effects regression for *diftotal*

```
Random-effects GLS regression                   Number of obs      =       875
Group variable (i): mun_number                  Number of groups   =       270

R-sq:  within  = 0.0337                         Obs per group: min =         1
       between = 0.3038                                        avg =       3.2
       overall = 0.2837                                        max =         4

Random effects u_i ~ Gaussian                   Wald chi2(4)       =    134.18
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
    diftotal |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        m3_1 |   -1.04626    .334637    -3.13   0.002    -1.702136   -.3903834
       m3_10 |  -1.060509   .2983413    -3.55   0.000    -1.645247   -.4757708
       m3_20 |   -.227879   .1258336    -1.81   0.070    -.4745084    .0187504
 calc_tariff |   .8516667   .1215123     7.01   0.000      .613507    1.089826
       _cons |   .2064288   .1411448     1.46   0.144      -.07021    .4830675
-------------+----------------------------------------------------------------
     sigma_u |  .90842123
     sigma_e |  .75101607
         rho |  .59400871   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Figure 3: Davidson and MacKinnon test of exogeneity for *mptotal*

```
. xtivreg consumption diftotalz fixedtotal income temp prec seasonal_dwelling
bathroom elder wat
> erqual (mptotal = privcompany munservices muncompany m3_5 m3_10 m3_15
calc_tariff), fe

Fixed-effects (within) IV regression         Number of obs      =        850
Group variable: mun_number                   Number of groups   =        267

R-sq:  within  = 0.0641                      Obs per group: min =          1
       between = 0.0001                                     avg =        3.2
       overall = 0.0009                                     max =          4

                                             Wald chi2(8)       =  30904.03
corr(u_i, Xb)  = -0.3103                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     mptotal |   1.112232   1.514794     0.73   0.463     -1.85671    4.081175
   diftotalz |   .4637802   .3302104     1.40   0.160    -.1834202    1.110981
  fixedtotal |   -.083323   .1528945    -0.54   0.586    -.3829908    .2163448
      income |  -.0070346   .0789411    -0.09   0.929    -.1617562     .147687
        temp |  -.4811799   .2635089    -1.83   0.068    -.9976479     .035288
        prec |  -.0003866    .000234    -1.65   0.098    -.0008452     .000072
seasonal_d~g |  (dropped)
    bathroom |  (dropped)
       elder |  -5.488469   6.626389    -0.83   0.408    -18.47595    7.499015
   waterqual |  -.8139563   1.889873    -0.43   0.667     -4.51804    2.890128
       _cons |   16.22505   4.565677     3.55   0.000     7.276485    25.17361
-------------+----------------------------------------------------------------
     sigma_u |  2.1666914
     sigma_e |  1.2409905
         rho |  .75298253   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F  test that all u_i=0:     F(266,575) =     4.72         Prob > F    = 0.0000
------------------------------------------------------------------------------
Instrumented:   mptotal
Instruments:    diftotalz fixedtotal income temp prec seasonal_dwelling
bathroom elder waterqual
                privcompany munservices muncompany m3_5 m3_10 m3_15
calc_tariff

. dmexogxt

Davidson-MacKinnon test of exogeneity:  .0622942  F( 1,574)  P-value =   .803
```

Figure 4: Davidson and MacKinnon test of exogeneity for *diftotal*

```
. xtivreg consumption mptotalz fixedtotal income temp prec seasonal_dwelling
bathroom elder wate
> rqual (diftotal = m3_1 m3_10 m3_20 calc_tariff), fe

Fixed-effects (within) IV regression         Number of obs      =        850
Group variable: mun_number                   Number of groups   =        267

R-sq:  within  =      .                      Obs per group: min =          1
       between = 0.1107                                     avg =        3.2
       overall = 0.1089                                     max =          4

                                             Wald chi2(8)       =   14628.74
corr(u_i, Xb)  = -0.6592                     Prob > chi2        =     0.0000

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    diftotal |   .9810227    .584656     1.68   0.093    -.1648821    2.126927
    mptotalz |    .310013   1.120028     0.28   0.782    -1.885202    2.505228
  fixedtotal |   .0827221   .1647335     0.50   0.616    -.2401497    .4055939
      income |   .0871687     .10728     0.81   0.416    -.1230963    .2974337
        temp |  -.8470755   .4475978    -1.89   0.058    -1.724351    .0302002
        prec |  -.0008211   .0003662    -2.24   0.025    -.0015388   -.0001035
seasonal_d~g |  (dropped)
    bathroom |  (dropped)
       elder |  -13.85398   10.76377    -1.29   0.198    -34.95059    7.242617
   waterqual |  -1.836498   2.825884    -0.65   0.516     -7.37513    3.702134
       _cons |   24.14597   8.133092     2.97   0.003     8.205404    40.08654
-------------+----------------------------------------------------------------
     sigma_u |  2.9482308
     sigma_e |  1.8038571
         rho |  .72761512   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F  test that all u_i=0:     F(266,575) =     1.74         Prob > F    = 0.0000
------------------------------------------------------------------------------
Instrumented:   diftotal
Instruments:    mptotalz fixedtotal income temp prec seasonal_dwelling
bathroom elder waterqual
                m3_1 m3_10 m3_20 calc_tariff

. dmexogxt

Davidson-MacKinnon test of exogeneity:  32.49871  F( 1,574)  P-value =  1.9e-
08
```

The relevance and the validity of the instruments used were tested through the Anderson and Sargan tests, respectively, making use of the xtivreg2 command (Schaffer (2007)).The null hypothesis of underidentification of the former test is rejected while the null of instrument validity of the latter is not, which is a good measure of the quality of the instruments used for both $mptotal$ and $diftotal$, as can be seen in Figures 5 and 6. Difference-in-Sargan tests were performed on each separate instrument for $mptotal$ and $diftotal$ to check their individual validity as instruments. None of the tests rejected the null.

Figure 5: Tests of instrument relevance and validity for *mptotal*

```
. xtivreg2 consumption diftotalz fixedtotal income temp prec seasonal_dwelling bathroom
elder waterqual (mptotal = privcompany munservices muncompany m3_5 m3_10 m3_15
calc_tariff)
> , fe
Warning - singleton groups detected.  18 observation(s) not used.
Warning - collinearities detected
Vars dropped:  seasonal_dwelling bathroom

FIXED EFFECTS ESTIMATION
------------------------
Number of groups =       249                    Obs per group: min =         2
                                                               avg =       3.3
                                                               max =         4

IV (2SLS) estimation
--------------------

Estimates efficient for homoskedasticity only
Statistics consistent for homoskedasticity only

                                                      Number of obs =      832
                                                      F(  8,   575) =     0.91
                                                      Prob > F      =   0.5059
Total (centered) SS     =  946.2144463                Centered R2   =   0.0641
Total (uncentered) SS   =  946.2144463                Uncentered R2 =   0.0641
Residual SS             =  885.5329826                Root MSE      =    1.232

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     mptotal |   1.112232   1.504365     0.74   0.460     -1.83627    4.060734
   diftotalz |   .4637802   .3279369     1.41   0.157    -.1789644    1.106525
  fixedtotal |   -.083323   .1518419    -0.55   0.583    -.3809277    .2142816
      income |  -.0070346   .0783976    -0.09   0.929     -.160691    .1466218
        temp |  -.4811799   .2616947    -1.84   0.066    -.9940921    .0317323
        prec |  -.0003866   .0002324    -1.66   0.096     -.000842    .0000688
       elder |  -5.488469   6.580768    -0.83   0.404    -18.38654    7.409599
   waterqual |  -.8139563   1.876862    -0.43   0.665    -4.492539    2.864626
------------------------------------------------------------------------------
Underidentification test (Anderson canon. corr. LM statistic):          16.076
                                                   Chi-sq(7) P-val =    0.0244
------------------------------------------------------------------------------
Weak identification test (Cragg-Donald Wald F statistic):                2.305
Stock-Yogo weak ID test critical values:  5% maximal IV relative bias    19.86
                                         10% maximal IV relative bias    11.29
                                         20% maximal IV relative bias     6.73
                                         30% maximal IV relative bias     5.07
                                         10% maximal IV size             31.50
                                         15% maximal IV size             17.38
                                         20% maximal IV size             12.48
                                         25% maximal IV size              9.93
Source: Stock-Yogo (2005).  Reproduced by permission.
------------------------------------------------------------------------------
Sargan statistic (overidentification test of all instruments):           6.333
                                                   Chi-sq(6) P-val =    0.3870
------------------------------------------------------------------------------
Instrumented:         mptotal
Included instruments: diftotalz fixedtotal income temp prec elder waterqual
Excluded instruments: privcompany munservices muncompany m3_5 m3_10 m3_15
                      calc_tariff
Dropped collinear:    seasonal_dwelling bathroom
------------------------------------------------------------------------------
```

Figure 6: Tests of instrument relevance and validity for *diftotal*

```
. xtivreg2 consumption mptotalz fixedtotal income temp prec seasonal_dwelling bathroom
elder waterqual (diftotal = m3_1 m3_10 m3_20 calc_tariff), fe
Warning - singleton groups detected.  18 observation(s) not used.
Warning - collinearities detected
Vars dropped:  seasonal_dwelling bathroom

FIXED EFFECTS ESTIMATION
------------------------
Number of groups =       249                   Obs per group: min =         2
                                                              avg =       3.3
                                                              max =         4

IV (2SLS) estimation
--------------------

Estimates efficient for homoskedasticity only
Statistics consistent for homoskedasticity only

                                                      Number of obs =      832
                                                      F(  8,   575) =     0.68
                                                      Prob > F      =   0.7085
Total (centered) SS     =  946.2144463                Centered R2   =  -0.9773
Total (uncentered) SS   =  946.2144463                Uncentered R2 =  -0.9773
Residual SS             =  1870.992685                Root MSE      =    1.791

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    diftotal |   .9810227   .5806308     1.69   0.091    -.1569928    2.119038
    mptotalz |    .310013   1.112317     0.28   0.780    -1.870088    2.490114
  fixedtotal |   .0827221   .1635994     0.51   0.613    -.2379268     .403371
      income |   .0871687   .1065414     0.82   0.413    -.1216487     .295986
        temp |  -.8470755   .4445162    -1.91   0.057    -1.718311    .0241603
        prec |  -.0008211   .0003636    -2.26   0.024    -.0015338   -.0001084
       elder |  -13.85398   10.68966    -1.30   0.195    -34.80534    7.097372
   waterqual |  -1.836498   2.806429    -0.65   0.513    -7.336997    3.664002
------------------------------------------------------------------------------
Underidentification test (Anderson canon. corr. LM statistic):          16.368
                                                   Chi-sq(4) P-val =    0.0026
------------------------------------------------------------------------------
Weak identification test (Cragg-Donald Wald F statistic):                4.131
Stock-Yogo weak ID test critical values:  5% maximal IV relative bias    16.85
                                         10% maximal IV relative bias    10.27
                                         20% maximal IV relative bias     6.71
                                         30% maximal IV relative bias     5.34
                                         10% maximal IV size             24.58
                                         15% maximal IV size             13.96
                                         20% maximal IV size             10.26
                                         25% maximal IV size              8.31
Source: Stock-Yogo (2005).  Reproduced by permission.
------------------------------------------------------------------------------
Sargan statistic (overidentification test of all instruments):           1.877
                                                   Chi-sq(3) P-val =    0.5982
------------------------------------------------------------------------------
Instrumented:         diftotal
Included instruments: mptotalz fixedtotal income temp prec elder waterqual
Excluded instruments: m3_1 m3_10 m3_20 calc_tariff
Dropped collinear:    seasonal_dwelling bathroom
------------------------------------------------------------------------------
```

For the next steps after correcting for endogenous regressors we follow the procedure by Dalmas and Reynaud (2005) and Reynaud (2008) and start by testing the presence of specific municipal effects in the data, i.e., comparing the random effects model with pooled OLS through a Breusch-Pagan Lagrangian multiplier test for random effects. Figure 7 shows that the null hypothesis of no specific municipal effects is clearly rejected, supporting the two-error components model presented in (20).

Figure 7: Breusch-Pagan Lagrangian multiplier test for random effects

```
. quietly xtreg consumption mptotalz diftotalz fixedtotal income temp prec
seasonal_dwelling bathroom elder waterqual, re

. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects:

        consumption[mun_number,t] = Xb + u[mun_number] + e[mun_number,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               consump~n |   4.963923       2.227986
                       e |   1.627386        1.27569
                       u |   1.923353        1.38685

        Test:   Var(u) = 0
                              chi2(1) =   226.29
                          Prob > chi2 =     0.0000
```

Before we resort to the Hausman test for the choice between random and fixed effects estimation, we perform tests for heteroskedasticity and autocorrelation, respectively through the commands xttest3 and xtserial. xttest3 implements a modified Wald test for group heteroskedasticity and we can see from Figure 8 that the null hypothesis of homoskedasticity is clearly rejected. xtserial implements an autocorrelation test discussed by Wooldridge (2001) for linear panel data models. Figure 8 shows that the null hypothesis of no autocorrelation in the residuals is also rejected. We adopt therefore a feasible GLS estimator developed by Baltagi and Wu (1999) and implemented through the Stata command xtregar.[33]

The Hausman test statistic for the comparison of the models with random

[33] In this aspect, our procedure departs from Dalmas and Reynaud (2005) and Reynaud (2008), who perform the Hausman test after the BP-LM test without testing for serial correlation, and is similar to the one used by Martins and Fortunato (2007).

Figure 8: Heteroskedasticity and autocorrelation tests

```
. quietly xtreg consumption mptotalz diftotalz fixedtotal income temp prec
seasonal_dwelling bathroom elder waterqual, fe
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (267)  =    1.1e+31
Prob>chi2 =      0.0000


. xtserial consumption mptotalz diftotalz fixedtotal income temp prec seasonal_dwelling
bathroom elder waterqual

Wooldridge test for autocorrelation in panel data
H0: no first order autocorrelation
    F(  1,     197) =      7.603
           Prob > F =      0.0064
```

and fixed effects has the value of 8.44, which corresponds to a p-value of 0.3921 in a $\chi^2(8)$. The test does not reject the null hypothesis of independence between the municipal effects and the exogenous regressors. Therefore, the GLS estimator is not only efficient but also consistent.

Figure 9 presents the estimation results. All coefficients have the expected signs and the great majority is significant at the 1% level. The value at the sample variable means for the price-elasticity of demand is -0.124, a relatively small value, but in line with the established result that water demand is price-inelastic. The estimated value is significantly lower than the value of -0.558 estimated by Martins and Fortunato (2007) for 5 Portuguese municipalities with monthly aggregate data[34] but is similar to the values estimated by Arbués-Gracia, Ortí and Martín (2008), Martínez-Espiñeira and Nauges (2004) and Martínez-Espiñeira (2002) respectively for Zaragoza, Seville and Galicia in Spain, Reynaud (2008) and Nauges and Reynaud (2001) for the southwest of France or Grafton and

[34] Our own estimation with our data for the 5 municipallities used by Martins and Fortunato (2007) yielded a price-elasticity of -0.187, which reveals that this municipalities have an above average reaction to price changes, but most of the difference is probably explained simply by the fact that the data used by both studies has rather different characteristics. Dalhuisen et al. (2003) have shown that the frequency of the data can have a significantly impact on the estimated price-elasticity and that estimations from monthly data usually yield more elastic results than with annual data. The only comparable estimation performed on the INSAAR data for all Portuguese water utilities in 2002 was done by Martins and Fortunato (2004), but this work does not find a significant coefficient for the price variable.

Ward (2007) for Sydney in the New South Wales region of Australia. All these regions have weather conditions similar to what can be found in Portugal. The income elasticity is 0.036, also a low value. Curiously, low values estimated for income elasticities are also not unheard of for regions at latitudes similar to Portugal and with close weather conditions as can be seen from Martínez-Espiñeira and Nauges (2004) for Spain, Nauges and Thomas (2000), Nauges and Reynaud (2001) and Garcia and Reynaud (2004) for France, Mylopoulos, Mentes and Theodossio (2004) for Greece, Nauges and Blundell (2002) for Cyprus, Yoo (2007) for South Korea, Barkatullah (1996) for Australia or Nieswiadomy and Molina (1991) for Texas, USA. The coefficients for the variables which together compose the usual "difference" variable in the Taylor-Nordin price specification, here decomposed into the block subsidy effect and the fixed charge, carry the expected negative signs but are not significantly different from zero. This may be a demonstration that consumers are not aware of the block subsidy effect or simply do not react to it for being small in comparison to their household income. The fact that $fixedtotal$ does not affect water demand is expected and supported by economic theory due to the fact that it is a fixed charge which does not vary with the amount of water consumed.

Figure 9: Estimation results

```
RE GLS regression with AR(1) disturbances       Number of obs      =       850
Group variable (i): mun_number                  Number of groups   =       267

R-sq:  within  = 0.0007                         Obs per group: min =         1
       between = 0.4181                                        avg =       3.2
       overall = 0.3360                                        max =         4

                                                Wald chi2(11)      =    192.44
corr(u_i, Xb)      = 0 (assumed)                Prob > chi2        =    0.0000

------------------- theta --------------------
  min      5%       median        95%      max
0.2532   0.3471     0.4618     0.4618   0.4618

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    mptotalz |  -1.514943   .4533426    -3.34   0.001    -2.403478   -.6264076
   diftotalz |  -.2115921   .1847499    -1.15   0.252    -.5736952     .150511
  fixedtotal |  -.0484121   .0682318    -0.71   0.478     -.182144    .0853197
      income |   .0769521   .0299292     2.57   0.010     .0182919    .1356124
        temp |   .2852466   .0831483     3.43   0.001     .1222789    .4482144
        prec |  -.0002155   .0001675    -1.29   0.198    -.0005438    .0001129
seasonal_d~g |  -3.989319   1.093954    -3.65   0.000    -6.133429   -1.845208
    bathroom |  -5.705003   2.127202    -2.68   0.007    -9.874242   -1.535765
       elder |   -8.28573   1.913328    -4.33   0.000    -12.03579   -4.535676
   waterqual |  -3.249893   1.568429    -2.07   0.038    -6.323957   -.1758281
       _cons |   7.260047   1.547328     4.69   0.000      4.22734    10.29275
-------------+----------------------------------------------------------------
      rho_ar |   .1783168   (estimated autocorrelation coefficient)
     sigma_u |  1.2073364
     sigma_e |  1.3339888
     rho_fov |  .45028633   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

The weather related variables have the expected signs, i.e., water demand increases with temperature and decreases with the amount of precipitation, although the coefficient for the latter is not significantly different from zero[35]. As expected, the % of seasonally inhabited dwellings has a significant negative effect on water consumption as does the % of houses without a bathtub or a shower. The negative coefficient for the % of people with 65 or more years of age confirms the previous findings. Finally the significant and negative coefficient for *waterqual* is a result which supports the view that consumers are aware of the tap water quality and do decrease their consumption when they consider it inadequate, perhaps turning to bottled water, private boreholes and wells or public fountains for their drinking and cooking water needs. This finding adds to the evidence brought up by Ford and Ziegler (1981), the only other study we are aware of that included delivered water quality as an explanatory factor for residential water demand.

Some authors like Foster and Beattie (1981) criticize the Taylor-Nordin price specification for assuming a fully informed consumer who is aware of the entire rate schedule and who responds to it accordingly. They argue that the consumer may only be aware of the total values of water expenditures and water consumption, supporting the use of an average price specification. Nieswiadomy and Molina (1991) apply the test procedure developed by Shin (1985) to test whether the consumer responds to the marginal or the average price (*aptotal*) of water. They consider the following "price perception variable", where k is the price perception parameter to be estimated:

$$P^{*} = mptotal \times \left(\frac{aptotal}{mptotal} \right)^{k} \tag{25}$$

A value of 0 for k would mean that consumers were responding to marginal price, rather than average price, while a value of 1 would have the opposite meaning. The adaptation of the test to our panel data framework proceeds as

[35] Perhaps a different specification for the rainfall variable could be a better explanatory variable for residential water demand. For example, some authors like Olmstead et al. (2007) transform it into a measure of effective rainfall ans subtract it from potential evapotranspitation to get a variable representing the moisture requirement for lawns. Others like Schleich and Hillenbrand (2007) consider only the rainfall occured in the summer months. Hoffmann, Worthington and Higgs (2006) choose to use the number of rainy days, instead of the actual amount of precipitation.

follows. The ratio $\frac{aptotal}{mptotal}$ ($perceived$) is included in a double-log functional form for water demand which is of subsequently estimated (Z_{it} is the vector of the remaining exogenous regressors in logarithmic form and δ_3 the vector of their associated coefficients).

$$\ln consumption_{it} = \delta_1 + \delta_2 \ln mptotal_{it} + \delta_2 k \ln perceived_{it} + \delta_3 Z_{it}^{'} + \alpha_i + \varepsilon_{it} \quad (26)$$

The error structure is similar to (21). k can be recovered after the estimation of (26) by dividing the coefficients associated with $\ln perceived$ and $\ln mptotal$. Because the endogeneity suspicions apply to the average price as well as the marginal price, we start by instrumenting it in the same fashion as we did with $mptotal$ and $diftotal$.

$$aptotal_{it} = \psi_1 + \psi_2 fixedtotal_{it} + \psi_3 m3\_10_{it} + \psi_4 calc\_tariff_{it} + \alpha_i + \varepsilon_{it} \quad (27)$$

The estimation results from a random effects model for (27) are shown in Figure 10.

Figure 10: Random effects regression for *aptotal*

```
Random-effects GLS regression                   Number of obs      =       856
Group variable (i): mun_number                  Number of groups   =       268

R-sq:  within  = 0.5743                         Obs per group: min =         1
       between = 0.8227                                        avg =       3.2
       overall = 0.7979                                        max =         4

Random effects u_i ~ Gaussian                   Wald chi2(3)       =   2022.11
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
     aptotal |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  fixedtotal |   .1813971   .0053863    33.68   0.000     .1708401     .191954
      m3_10 |   .4828797   .0305547    15.80   0.000     .4229936    .5427658
 calc_tariff |   .0583706   .0162785     3.59   0.000     .0264653    .0902759
       _cons |   .1154036   .0187585     6.15   0.000     .0786376    .1521695
-------------+----------------------------------------------------------------
     sigma_u |  .12767887
     sigma_e |  .09362701
         rho |  .65030926   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Figure 11 shows the low p-value for the Davidson and MacKinnon test of exogeneity which indicates that the null hypothesis of exogeneity cannot be accepted with confidence, which supports the usual option on instrumenting the price variables in the presence of block tariffs[36].

[36] The Hausman test is not computable for this case.

Figure 11: Davidson and MacKinnon test of exogeneity for *aptotal*

```
. xtivreg consumption income temp seasonal_dwelling bathroom elder waterqual (aptotal =
fixedtotal m3_10 calc_tariff), fe

Fixed-effects (within) IV regression         Number of obs      =        850
Group variable: mun_number                   Number of groups   =        267

R-sq:  within  = 0.0026                      Obs per group: min =          1
       between = 0.0580                                     avg =        3.2
       overall = 0.0650                                     max =          4

                                             Wald chi2(5)       =  29141.60
corr(u_i, Xb)  = 0.1881                      Prob > chi2        =    0.0000

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     aptotal |  -.1085296   .4950299    -0.22   0.826     -1.07877    .8617112
      income |   .0233495   .0710764     0.33   0.743    -.1159577    .1626567
        temp |  -.0913173   .2123334    -0.43   0.667    -.5074831    .3248485
seasonal_d~g |  (dropped)
    bathroom |  (dropped)
       elder |  -2.640374   6.688423    -0.39   0.693    -15.74944    10.46869
   waterqual |  -.3808349   1.940894    -0.20   0.844    -4.184917    3.423247
       _cons |   9.441598   3.527226     2.68   0.007     2.528362    16.35483
-------------+----------------------------------------------------------------
     sigma_u |  2.0194139
     sigma_e |  1.2778256
         rho |  .71408243   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F  test that all u_i=0:     F(266,578) =     4.26         Prob > F    = 0.0000
------------------------------------------------------------------------------
Instrumented:   aptotal
Instruments:    income temp seasonal_dwelling bathroom elder waterqual fixedtotal m3_10
calc_tariff

. dmexogxt

Davidson-MacKinnon test of exogeneity:  3.779982  F( 1,577)  P-value =  .0524
```

Figure 12 shows that the Anderson test rejects the null hypothesis of under-identification, thus supporting the relevance of the instruments chosen, while the Sargan test does not reject the null hypothesis of the instruments' validity. Separate difference-in-Sargan tests were performed on each instrument to check their individual validity as instruments for *aptotal*. None of the tests rejected the null hypothesis.

Figure 12: Tests of instrument relevance and validity for *aptotal*

```
. xtivreg2 consumption income temp seasonal_dwelling bathroom elder waterqual (aptotal =
fixedtotal m3_10 calc_tariff), fe
Warning - singleton groups detected.  18 observation(s) not used.
Warning - collinearities detected
Vars dropped:  seasonal_dwelling bathroom

FIXED EFFECTS ESTIMATION
------------------------
Number of groups =       249                   Obs per group: min =         2
                                                              avg =       3.3
                                                              max =         4

IV (2SLS) estimation
--------------------

Estimates efficient for homoskedasticity only
Statistics consistent for homoskedasticity only

                                                      Number of obs =      832
                                                      F(  5,   578) =     0.10
                                                      Prob > F      =   0.9928
Total (centered) SS     =  946.2144463                Centered R2   =   0.0026
Total (uncentered) SS   =  946.2144463                Uncentered R2 =   0.0026
Residual SS             =  943.7805394                Root MSE      =    1.272

------------------------------------------------------------------------------
 consumption |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     aptotal |  -.1085296   .4929026    -0.22   0.826    -1.074601    .8575417
      income |   .0233495    .070771     0.33   0.741    -.1153591     .162058
        temp |  -.0913173   .2114209    -0.43   0.666    -.5056946      .32306
       elder |  -2.640374    6.65968    -0.40   0.692    -15.69311    10.41236
   waterqual |  -.3808349   1.932553    -0.20   0.844    -4.168569    3.406899
------------------------------------------------------------------------------
Underidentification test (Anderson canon. corr. LM statistic):          332.424
                                                   Chi-sq(3) P-val =    0.0000
------------------------------------------------------------------------------
Weak identification test (Cragg-Donald Wald F statistic):               254.715
Stock-Yogo weak ID test critical values:  5% maximal IV relative bias    13.91
                                         10% maximal IV relative bias     9.08
                                         20% maximal IV relative bias     6.46
                                         30% maximal IV relative bias     5.39
                                         10% maximal IV size             22.30
                                         15% maximal IV size             12.83
                                         20% maximal IV size              9.54
                                         25% maximal IV size              7.80
Source: Stock-Yogo (2005).  Reproduced by permission.
------------------------------------------------------------------------------
Sargan statistic (overidentification test of all instruments):            1.623
                                                   Chi-sq(2) P-val =    0.4441
------------------------------------------------------------------------------
Instrumented:         aptotal
Included instruments: income temp elder waterqual
Excluded instruments: fixedtotal m3_10 calc_tariff
Dropped collinear:    seasonal_dwelling bathroom
------------------------------------------------------------------------------
```

After the model (26) was estimated (see results in Figure 13) the following nonlinear hypothesis were tested:

$$H_0 : \frac{\delta_2 k}{\delta_2} = 0 \tag{28}$$

$$H_0 : \frac{\delta_2 k}{\delta_2} = 1 \tag{29}$$

The test statistic for (28) is 0.23 which corresponds to a p-value of 0.6326 in a $\chi^2(1)$. The test statistic for (29) is 8.66 which corresponds to a p-value of 0.0033 in a $\chi^2(1)$. The result is therefore very clear. (28) is not rejected while (29) is, meaning that Portuguese consumers do respond to the marginal price and not to the average price of water.

Figure 13: Estimation result of the auxiliary model for the price perception test

```
RE GLS regression with AR(1) disturbances       Number of obs      =       807
Group variable (i): mun_number                  Number of groups   =       264

R-sq:  within  = 0.0027                         Obs per group: min =         1
       between = 0.5061                                        avg =       3.1
       overall = 0.4095                                        max =         4

                                                Wald chi2(9)       =    255.60
corr(u_i, Xb)       = 0 (assumed)               Prob > chi2        =    0.0000

------------------- theta --------------------
  min      5%       median        95%      max
0.2692   0.3527     0.4588     0.4588   0.4588

------------------------------------------------------------------------------
lnconsumpt~n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  lnmptotalz |  -.1084412   .0312263    -3.47   0.001    -.1696437   -.0472387
 lnperceived |   .0210365   .0409271     0.51   0.607     -.059179    .1012521
    lnincome |   .0886064   .0250027     3.54   0.000     .0396019    .1376108
      lntemp |   .6992438   .1396011     5.01   0.000     .4256307    .9728568
lnseasonal~g |   -.123602   .0300307    -4.12   0.000    -.1824611   -.0647429
  lnbathroom |  -.0442686   .0276573    -1.60   0.109    -.0984759    .0099388
     lnelder |  -.2146465   .0527708    -4.07   0.000    -.3180754   -.1112176
 lnwaterqual |  -.0087782   .0067355    -1.30   0.192    -.0219796    .0044231
       _cons |  -.7855641   .3730974    -2.11   0.035    -1.516822   -.0543067
-------------+----------------------------------------------------------------
      rho_ar |  .25861855   (estimated autocorrelation coefficient)
     sigma_u |  .15487805
     sigma_e |  .16016525
     rho_fov |  .48322229   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

7 Functional form specification tests

We now turn to the question of choice of functional form. Table 7 presents the estimation results for the functional forms considered in Tables 1 and 2. The nonsignificant variables from the Figure 9 were removed[37]. All coefficients retain the expected signs already seen in Figure 9. Only *bathroom* and *waterqual* have somewhat less significant coefficients in specific functional forms. All other coefficients are always significant at the 1% level.

Table 8 presents the calculations of the demand elasticities for the several functional forms considered.We can see that the results for the price-elasticities are generally robust to the choice of functional form, with only small variations between them.

To choose between the several functional forms presented in Table 7 we focus on three different methods:

- an encompassing approach (Mizon and Richard (1986));
- a comprehensive approach (the J test) (Davidson and MacKinnon (1981));
- the PE test (MacKinnon, White and Davidson (1983)).

The first two approaches will be used to compare nonnested models with the same dependent variable, while the PE test will be used to compare models where consumption is defined in natural logarithms with models where it is introduced without that transformation.

The encompassing approach starts by assuming one of the models being compared as the base model. Then it proceeds to create and estimate a model were the variables from the alternative model not included in the base model are added to it. The null hypothesis of the test is that the coefficients of these additional variables are all zero. A t-test or a Waldman F-test, depending on whether one or more additional regressors were added to the base model, is performed to test the null hypothesis and the validity of the base model. The role of each model can be reversed and the test performed again to the test the

[37] Besides the usual advantages for efficiency of removing insignificant variables from an econometric model, the removal of *diftotal* has the additional advantage of enabling the estimation of the linlog and double-log models, because it has both negative, null and positive values.

validity of the alternative model[38].

[38] See Greene (2003), p. 154, and Verbeek (2000), pp. 55-6, for further details.

Table 7: GLS regressions with AR(1) disturbances for several functional forms

Functional form	**Linear**	**Double-log**	**Log-lin**	**Lin-log**	**Stone-Geary**
Variable	Coef.	Coef.	Coef.	Coef.	Coef.
	(Std. Err.)	(Std. Err.)	(Std. Err.)	(Std. Err.)	(Std. Err.)
mptotalz	-1.236***	-0.111***	-0.154***	-0.910***	-
	(0.360)	(0.027)	(0.045)	(0.213)	-
income	0.079***	0.091***	0.010***	0.594***	-
	(0.030)	(0.025)	(0.004)	(0.193)	-
$(\text{income}*10^3)$/mptotalz	-	-	-	-	0.001***
	-	-	-	-	(0.000)
temp	0.342***	0.682***	0.049***	4.284***	0.330***
	(0.072)	(0.138)	(0.010)	(1.055)	(0.072)
seasonal_dwelling	-3.952***	-0.124***	-0.647***	-0.891***	-3.429***
	(1.087)	(0.030)	(0.140)	(0.226)	(1.055)
bathroom	-5.815***	-0.043†	-0.867***	-0.382*	-4.608**
	(2.120)	(0.027)	(0.273)	(0.209)	(2.056)
elder	-7.353***	-0.211***	-1.025***	-1.409***	-7.141***
	(1.840)	(0.052)	(0.235)	(0.394)	(1.844)
waterqual	-2.807*	-0.009	-0.374**	-0.065	-2.128
	(1.508)	(0.007)	(0.182)	(0.054)	(1.505)
intercept	5.864***	-0.734**	1.739***	-10.259***	4.841***
	(1.251)	(0.368)	(0.159)	(2.825)	(1.206)
N	873	830	873	830	873
Wald $\chi^2(7)$	188.82	259.42	246.29	211.40	184.07
Prob $>\chi^2(7)$	0.000	0.000	0.000	0.000	0.000
Price-elasticity	-0.101	-0.111	-0.094	-0.122	-0.052
Income-elasticity	0.037	0.091	0.033	0.078	0.001

*** Significance at the 0.01 level

** Significance at the 0.05 level

* Significance at the 0.10 level

† Significance at the 0.15 level

Table 8: Summary of elasticity results for several functional forms

Functional form	**Linear**	**Double-log**	**Log-lin**	**Lin-log**	**Stone-Geary**
Variable	Elast.	Elast.	Elast.	Elast.	Elast.
mptotalz	-0.101	-0.111	-0.094	-0.122	-0.052
income	0.037	0.091	0.033	0.078	0.001
temp	0.700	0.682	0.748	0.574	0.675
seasonal_dwelling	-0.127	-0.124	-0.155	-0.119	-0.110
bathroom	-0.076	-0.043	-0.085	-0.051	-0.060
elder	-0.205	-0.211	-0.214	-0.189	-0.199
waterqual	-0.153	-0.009	-0.015	-0.009	-0.012

The comprehensive approach or J-test consists of adding to the base model the fitted values of the alternative model and testing whether or not they are significantly different from zero by means of a t-test[39]. The null hypothesis of a zero coefficient corresponds a valid base model.

Finally, the PE test for the validity of the model with the linear specification of the dependent variable (base model) involves adding to this base model the difference between the natural logarithm of the fitted values for the base model and the fitted values for the alternative model (the one with the dependent variable in logarithms). The null hypothesis that the coefficient of this additional regressor is zero, supports the linear model if it is not rejected and invalidates it against the alternative otherwise. To test the validity of the model with the dependent variable in logarithms we must add to the loglinear model the difference between fitted values of the linear model and the exponential function of the fitted values of the loglinear model. The null hypothesis for this second model states that the coefficient of this additional regressor is zero. If rejected it invalidates the loglinear model, but if not rejected, then it may be preferable. The PE test is an adaptation of the J-test for different dependent variables[40].

Table 9 shows the results of the relevant specification tests for comparing the different functional forms and the preferred one for each comparison. Summing up, we can see that the semilogarithmic functional form log-lin performs worst than any of the alternatives. The Stone-Geary form is also rejected when compared to the linear or to the lin-log semilogarithmic forms. The linear functional form is also not the preferred as it is discarded when compared to the lin-log alternative. The only alternative which is not rejected when compared with the lin-log is the double-log specification. The PE test rejects either form and none is preferred. The double-log specification is preferred to the semilogarithmic log-lin, but the tests fail to decide when it is compared to any of the other three alternatives. In the end we are left with an inconclusive choice between the semilogarithmic lin-log functional for and the double-log specification. This is unfortunate as we have seen that the former would justify IBT, while the latter would recommend an uniform volumetric rate (either of them coupled with a

[39] See Greene (2003), pp. 154-5, and Verbeek (2000), p. 56, for further details.

[40] See Greene (2003), pp. 178-80, and Verbeek (2000), p. 56-7, for further details.

fixed charge, leading to a multi-part tariff for the former and a two-part tariff for the latter).

Table 9: Specification tests results and resulting preferred functional form

Funct. form	**Double-log**	**Log-lin**	**Lin-log**	**Stone-Geary**
Linear	undetermined	Linear	Lin-log	Linear
Encompassing	-	-	(H_0: linear; F-test: 0.070)	(H_0: linear; t-test: 0.365)
	-	-	(H_0: lin-log; F-test: 0.822)	(H_0: SG; F-test: 0.152)
Comprehensive	(H_0: linear; t-test: 0.016)	(H_0: linear; t-test: 0.537)	(H_0: linear; t-test: 0.002)	(H_0: linear; t-test: 0.365)
(J-test or PE-test)	(H_0: d-log; t-test: 0.003)	(H_0: log-lin; t-test: 0.000)	(H_0: lin-log; t-test: 0.558)	(H_0: SG; t-test: 0.065)
Double-log	-	Double-log	undetermined	undetermined
Encompassing		(H_0: d-log; F-test: 0.404)	-	-
		(H_0: log-lin; F-test: 0.025)	-	-
Comprehensive		(H_0: d-log; t-test: 0.227)	(H_0: d-log; t-test: 0.000)	(H_0: log-lin; t-test: 0.020)
(J-test or PE-test)		(H_0: log-lin; t-test: 0.001)	(H_0: lin-log; t-test: 0.002)	(H_0: SG; t-test: 0.001)
Log-lin	-	-	Lin-log	Stone-Geary
Comprehensive			(H_0: log-lin; t-test: 0.000)	(H_0: log-lin; t-test: 0.535)
(J-test or PE-test)			(H_0: lin-log; t-test: 0.472)	(H_0: SG; t-test: 0.002)
Lin-log	-	-	-	Lin-log
Encompassing				(H_0: lin-log; F-test: 0.783)
				(H_0: SG; F-test: 0.031)
Comprehensive				(H_0: lin-log; t-test: 0.639)
(J-test or PE-test)				(H_0: SG; t-test: 0.000)

Our analysis of the Portuguese residential water demand does not enable us to conclude if the IBT universally applied by the Portuguese water utilities for residential water supply and to a much lesser extent to the wastewater component of the water bill can be grounded on efficiency reasons, besides the usual justifications for its implementation based on equity or water conservation concerns. We were, nevertheless, unable to dismiss this possibility when the conditions described by Roseta-Palma and Monteiro (2008) apply.

8 Conclusion

We tested the conditions derived by Roseta-Palma and Monteiro (2008) for IBT to be a second-best pricing practice under water scarcity and budget balancing constraints, when consumers are heterogeneous and the fixed charge is only allowed to cover fixed costs and not to act as a lump sum charge in order to guarantee cost recovery by the water utility. The choice of functional form, which is most usually based on convenience for the practical research objective at hand, is shown to be essential in determining the outcome of such a test. While a linear or semilogarithmic specifications would lead us to conclude that IBT are justified, a double-log functional form would recommend a uniform volumetric rate and a Stone-Geary specification would make the choice of tariff schedule design dependent on the estimated values of the coefficients associated with each regressor.

We estimate residential water demand for Portugal for a panel of annual data at the municipal level for four different years through a random effects GLS estimator with AR(1) disturbances and make the choice of functional form dependent on the appropriate statistical specification tests for comparing each pair of alternative hypothesis (like the J-test or the PE-test). We are left with an inconclusive choice between a semilogarithmic lin-log functional form and a double-log specification. Therefore it has not been proved that the use of IBT can have efficiency justifications, besides the usual equity and water conservation concerns, but such possibility could not be dismissed.

The results for the water demand determinants confirm that residential water demand does respond to the marginal and not to the average price, although it is inelastic. Besides the usual positive impact of income, temperature and water using appliances and the negative impact of the proportion of elderly people, we show that the proportion of seasonally inhabited dwellings and a reduced water quality on delivery can have a significant negative influence on the amount of water households consume.

Future research on the Portuguese water demand could try to improve the data available, gathering household level information to explicitly model the choice of consumption block and include more specific household characteristics, like gardens and pools. Intra-annual data would also be valuable in the identification of seasonal consumption patterns or in the separation of indoor and outdoor water demand, enabling further research on whether seasonally differentiated tariffs are called for. Furthermore, if the frequency of observations was similar to the billing frequency, lagged price specifications coud be tested and the speed of adoption of water saving measures in response to higher prices could also be investigated. Finally, the combination of water demand estimations with research on the costs of water supply and sewerage would be valuable to better assess the potential of the tariff schedules to contribute to the objectives set out by the Water Framework Directive for 2010 regarding the establishment of efficient water prices and adequate cost recovery levels. Furthermore, if cost savings could be made, by the water utilities by seizing economies of scale for example, adequate cost recovery levels might be achieved with a lesser impact on tariffs and consumers.

A Residential water demand estimation studies

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Bartczak et al.	2009	WP - Warsaw Ecological Economics Center, Warsaw University	Panel data (aggregate)	Annual (2001-2005)	RE-GLS, corrected for autocorrelation; FGLS, Paris-Winsten with panel-corrected standard errors	195 (39 municipal districs*5 years)	Poland	Double logarithmic (loglinear or log-log)	Residential
Diakité et al.	2009	Journal of Development Economics	Panel data (aggregate)	Annual (1998-2002)	Discrete-Continuous Choice model, multinomial logit for the choice of block and 3SLS, FE, OLS, GLS	780 (156 local communities*5 years)	Côte d'Ivoire	Linear	Residential
Garcia-Valiñas et al.	2009	Paper presented at the 17th Annual Conference of EAERE (EAERE 2008)	Panel data (aggregate)	Annual (1998, 2001 and 2004)	FE	6911	France	Stone-Geary	Residential
Olmstead	2009	Journal of Business and Economic Statistics	Panel data (household data)	Daily (2 weeks in wet season and 2 weeks in arid season)	Discrete-Continuous choice model (maximum likelihood); Panel datechniques (random effects); IV ("IV model is a two-stage GLS random-effects model for panel data."); Monte Carlo study of estimators' properties	1342 (671 households * 2 seasons)	7 urban areas (Denver, Seattle, San Diego, Tampa, Phoenix, Tempe/Scottsdale [USA] and Las Virgenes [Canada]) served by 10 water utilities (USA and Canada)	Double logarithmic (loglinear or log-log)	Residential
Ruijs	2009	Environmental and Resource Economics (forthcoming)	Time series (aggregate)	Monthly (July 1997-December 2002)	OLS	64	Metropolitan region of São Paulo (Brazil)	Linear	Residential
Schleich	2009	Paper presented at the 17th Annual Conference of EAERE (EAERE 2008)	Cross-section (aggregate data)	Annual (2003)	OLS	592 water supply areas in Germany	Germany	Stone-Geary, linear and Log-linear (log-log)	Residential
Schleich and Hillenbrand	2009	Ecological Economics	Cross-section (aggregate)	Annual (2003)	OLS and IV; Hausman test performed (no endogeneity found)	592 water supply areas in Germany	Germany	Double logarithmic (loglinear or log-log) and semilogarithmic (log-lin and lin-log)	Residential
Arbués-Gracia et al.	2008	Paper presented at the 3rd AERNA Congress	Panel data (household data)	Quarterly (10 meter readings between 1996 and 1998)	2 SLS, RE	15070 (1507 sampled households, 10 quarters)	Zaragoza (Spain)	Semilogarihmic (log-lin)	Residential
Azomahou	2008	Cliometrica	Panel data (aggregate)	Biannual (1988-1993)	2 stage autoregressive spatial model: maximum likelihood methods used in the first stage; minimum distance estimator used in the second stage	1380 (12 semesters * 115 municipalities)	115 municipalities from the department Moselle (out of 730 municipalities in this department) in northeast France (France)	Spatial autoregressive model	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Basani et al.	2008	World Development	Cross-section (household data)	Monthly (-)	2-step Heckman procedure, including selection model (probit) for connection and OLS	428 connected households + 354 non-connected households	Cambodja	Double logarithmic (loglinear or log-log)	Residential
Bell and Griffin	2008	Water Resources Research	Panel data (aggregate)	Monthly (1999-2003)	FE	18468 from an original data set of 23100 (385 water providers * 60 months)	Texas (USA)	Log-nonlinear (differences in logs)	Municipal
Cheesman et al.	2008	Water Resources Research	Panel data (household data)	Monthly (2006)	Contingent behavior, 2-step Heckman procedure, including selection model (probit), RE-GLS, SUR	390 (130 households, 1 revealed preference plus 2 contingent behavior responses per household)	Buon Ma Thuot, Dak Lak Province (Vietnam)	Double logarithmic (loglinear or log-log)	Residential
Frondel and Messner	2008	Paper presented at the 16th Annual Conference of EAERE (EAERE 2008) in a poster session	Panel data (household data)	Annual (1998-2001)	Endogenous switching regression model, Pooled OLS	760 (140 households*4 years)	Leipzig (Germany)	Double logarithmic (loglinear or log-log)	Residential
Kenney et al.	2008	Journal of the American Water Resources Association	Panel data (household data)	Monthly (2000-2005)	FE-IV	approximately 680000 (from over 10000 accounts)	Aurora, Colorado (USA)	Double logarithmic (loglinear or log-log)	Residential
Miyawaki et al.	2008	WP - Center for International Research on the Japanese Economy	Panel data (household data)	Monthly (June 2006-May 2008)	Bayesian estimation (Markov chain Monte Carlo simulation; Gibbs sampling). Discrete/Continuous Choice Model + Panel data techniques (RE and Dynamic panel data techniques)	365 (cross-section); 229 (panel; 2 periods: June 2006 and June 2007)	Tokyo and Chiba prefectures (Japan)	Double logarithmic (loglinear or log-log)	Residential
Nataraj and Hanemann	2008	CUDARE WP - Department of Agricultural & Resource Economics, University of California, Berkeley	Panel data (household data)	Bimonthly (July-August, 1990-2000)	Regression Discontinuity Design	103044 (from 9486 single-family households)	Santa Cruz, California (USA)	Linear	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Nauges and Berg	2008	Environmental and Resource Economics	Cross-section (household data)	Monthly (2003)	Simultaneous equations, IV (2SLS); 2-step Heckman procedure, including selection model (probit) for connection; Tobit model, ML	1718	Gampaha, Kalutara and Galle, Southwest Sri Lanka (Sri Lanka)	Double logarithmic (loglinear or log-log)	Residential
Reynaud	2008	Paper presented at the 16th Annual Conference of EAERE (EAERE 2008)	Panel Data (Aggregate)	Every 3 years (1998, 2001 and 2004)	Pooled OLS, FE, RE	904 observations (338 local communities * 3 years - removal of missing observations)	Midi-Pyrénées region in Southwest of France (France)	Double logarithmic (loglinear or log-log)	Residential
Ruijs et al.	2008	Ecological Economics	Time series (aggregate)	Monthly (July 1997-December 2002)	OLS (for the MP model); 2SLS (for the AP model)	64	Metropolitan region of São Paulo (Brazil)	Linear	Residential
Statzu and Strazzera	2008	Temi Economici della Sardegna - Quaderni di Lavoro Crenos 08/03	Panel data (aggregate)	Yearly (2000-2005)	FE, RE-GLS, Hausman-Taylor, Amemya-Mcurdy, Fixed-Effects Vector Decomposition	1440 (6 years*240 towns)	Sardinia (Italy)	Double logarithmic (loglinear or log-log)	Residential
Strong and Smith	2008	WP - NBER	Cross-section (aggregate)	Monthly (2005)	Nonlinear least squares; Discrete/Continuous Choice models	516 (43 utilities*12 months)	Phoenix, Arizona (USA)	Nonlinear	Residential
Xayavong et al.	2008	WP - The University of Western Australia, School of Agricultural and Resource Economics	Panel data (household data)	Annual (1995-2005)	ML, Tobit model to estimate the proportion of households per block	2390 (234 suburbs * 11 years)	Perth, Western Australia (Australia)	Linear	Residential
Babel et al.	2007	Water Resources Management	Time Series (Aggregate)	Annual (1988-2001)	OLS	14 (Annual observations 1988-2001)	Kathmandu Valley, Nepal	Linear, Semilogarithmic (log-lin); Double logarithmic (loglinear or log-log)	Residential
Dahan and Nisan	2007	Water Resources Research	Cross-section (household data)	Annual (2003)	OLS, 2 SLS, Discrete/Continuous Choice model (ML)	51167	Jerusalem (Israel)	Linear and double logarithmic (loglinear or log-log)	Residential
Fullerton et al.	2007	Atlantic Economic Journal	Time-series (Aggregate)	Monthly (January 1997-December 2003)	Multiple-input transfer function technique (LTF method: extension of the transfer ARIMA approach)	84	Tijuana (Mexico)	Linear	Municipal
Grafton and Kompas	2007	Australian Journal of Agricultural and Resource Economics	Time Series (Aggregate)	Daily (28/10/2001-30/09/2005)	OLS (with AR(1) process, White Heteroskedasticity Consistent Standard Errors & Covariance)	1142 (1434 after adjustments)	Sydney (Australia)	Double logarithmic (loglinear or log-log)	Residential
Grafton and Ward	2007	Australian Journal of Agricultural and Resource Economics	Time-series (Aggregate)	Daily (01/01/1994-30/09/2005)	OLS	4291	Sydney (Australia)	Double logarithmic (loglinear or log-log)	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Mansur and Olmstead	2007	WP - National Bureau of Economic Research	Panel data (household data)	Daily (2 two-week periods: summer, winter)	2SLS, ML, Tobit (outdoor demand), FE, RE	2164 (2 periods*1082 households)	11 urban areas (USA and Canada)	Semilogarithmic (log-lin)	Residential (only detached single family homes)
Martínez-Espiñeira	2007	Journal of Applied Economics	Time-series (Aggregate)	Monthly (1991-1999)	Co-integration, Error-correction model	108 (12 months * 9 years)	Seville (Spain)	Linear	Residential
Martins and Fortunato	2007	Water Policy	Panel data (aggregate)	Monthly (January 1998-December 2003)	IV, RE (with GLS and correction for a 1st order autoregressive disturbance process)	360 (5 local communities and 72 months)	Centre region (Portugal)	Linear	Residential
Musolesi and Nosvelli	2007	Applied Economics Letters	Panel data (aggregate)	Annual (1998-2001)	System GMM	408 (102 municipalities*4 years)	Cremona Province (Italy)	Double logarithmic (loglinear or log-log)	Residential
Nauges and Strand	2007	Resource and Energy Economics	Cross-section (household data)	Surveys performed between 1995-1997	two-step procedure: 1st step - multinomial logit model to select the water source; 2nd step OLS (with Lee correction method) on log-log functional form. Bootstrapping	1379 (553 non-tap households in El Salvador and 826 non-tap households in Honduras)	3 cities (El Salvador) and in marginal barrios in Tegucigalpa (Honduras)	Double logarithmic (loglinear or log-log) (2nd step)	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Olmstead et al.	2007	Journal of Environmental Economics and Management	Panel data (household data)	Daily (2 weeks in wet season and 2 weeks in arid season)	Discrete-Continuous choice model (DCC model) involving Maximum Likelihood estimation; A panel random-effects (GLS) model is estimated for uniform price observations only. Bootstrap used on elasticities	N=25666 (1082 households in 11 urban areas in the United States and Canada, served by 16 public water utilities; 4 weeks of daily measurements).	Denver, Eugene, Seattle, San Diego, Tampa, Phoenix, Tempe/Scottsdale, Waterloo/Cambridge (Ontario), Walnut Valley, Las Virgenes, and Lompoc (USA and Canada)	Double logarithmic (loglinear or log-log)	Residential
Yoo	2007	Applied Economics Letters	Cross-section (household data)	Monthly (2002)	Sample selection model (to detect and correct for sample selection bias)	804 households	Korean metropolitan cities (Seoul, Pusan, Daegu, Incheon, Kwangju, Daejeon and Ulsan) (South Korea)	Double logarithmic (loglinear or log-log)	Residential
Arbués and Villanua	2006	Urban Studies	Panel data (household data)	Quarterly (10 meter readings between 1996 and 1998)	Dynamic panel data techniques (two-step Arellano-Bond + Between estimator in another step to estimate the parameters of time-invariant variables)	15960 (10 meter readings in the period 1996-1998 * 1596 users)	Zaragoza (Spain)	Linear, double logarithmic (loglinear or log-log) and semilogarithmic (linear functional form chosen as best based on the Schwarz BIC criterion)	Residential
Fullerton et al.	2006	Atlantic Economic Journal	Time-series (Aggregate)	Monthly (2000-2004)	Linear Transfer Function ARIMA	60	Ciudad Juárez (Mexico)	Linear	Municipal
Garcia-Valiñas	2006	Applied Economics	Panel data (household and firm data)	Quarterly (1991(4)-2000 (3))	GMM	493992 (1372 households*36 quarters) and 9216 (256 firms*36 quarters)	Seville, Andalusia (Spain)	Linear	Residential and commercial/industrial
Gaudin	2006	Applied Economics	Cross-Section (Aggregate)	Annual	OLS (Hausman test performed with IV/2SLS on price endogeneity "log values of the total charges for 3750-gallon and 7500-gallon monthly bills are used in addition to the other exogenous variables to instrument price" (no evidence of systematic bias found)	383 water utilities	USA	Double logarithmic (loglinear or log-log)	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Hoffmann et al.	2006	Australian Journal of Agricultural and Resource Economics	Time series (aggregate)	Quarterly (September 1998 June 2003)	OLS	20 quarters	Brisbane (Australia)	Linear and double logarithmic (loglinear or log-log)	Residential
Jansen and Schulz	2006	South African Journal of Economics	Panel data (household data)	Monthly (July 1998-June 2003)	2SLS; Panel Corrected Standard Errors Model (PCSE); RE AR(1); FE AR(1); GLS; Pooled OLS	up to 16500 (unbalanced panel of 275 households and 60 months)	Cape Town (South Africa)	Double logarithmic (loglinear or log-log)	Residential
Kostas and Chrysostomos	2006	South-Eastern Europe Journal of Economics	Time series (aggregate)	Annual (1981-1999)	OLS	20	Athens (Greece)	Stone-Geary	Residential
Larson et al.	2006	Journal of Development Studies	Cross-section (household data)	Monthly (2000)	2-step Heckman procedure, including selection model (logit) for connection, ML	547	Fianarantsoa (Madagascar)	Linear	Residential
Mazzanti and Montini	2006	Applied Economics Letters	Panel data (aggregate)	Annual (1998-2001)	FE, chosen after Hausman test	500 (125 municipalities*4 years)	Emilia-Romagna (Italy)	Double logarithmic (loglinear or log-log)	Residential
Carter and Milon	2005	Land Economics	Panel data (household data)	Monthly (1997-1999)	Probit for the decision to acquire price knowledge, OLS; 2-stage Simultaneous equations techniques with endogenous switching	24695 from a potential of 26712 (742 households*36 months)	Florida (USA)	Double logarithmic (loglinear or log-log)	Residential
Dalmas and Reynaud	2005	Chapter in the book Koundouri (ed.) "Econometrics Informing Natural Resources Management: Selected Empirical Analyses"	Panel data (aggregate)	Annual (1999-2001)	RE-GLS, OLS	213 (3 years * 71 municipalities)	Slovak Republic	Linear, double logarithmic (loglinear or log-log) and Stone-Geary	Residential
García-Valiñas	2005	Environmental and Resource Economics	Panel data (household and firm data)	Quarterly (1991(4)-2000 (3))	GMM	493992 (1372 households*36 quarters) and 9216 (256 firms*36 quarters)	Seville, Andalusia (Spain)	Linear	Residential and industrial/commercial
García-Valiñas	2005	Revista de Economía Pública	Panel data (household and firm data)	Quarterly (1994-2000)	GMM, FE, Hausman tests, Sargan tests for instrument validity	41175 (1525 households*27 quarters) and 2160 (80 firms*27 quarters)	Elche, Alicante (Spain)	Linear	Residential and industrial/commercial

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
García-Valiñas	2005	Chapter in the book Koundouri (ed.) "Econometrics Informing Natural Resources Management: Selected Empirical Analyses"	Panel data (household and firm data)	Bimonthly (1994-2000)	System GMM	Residential: 65340 (1089 households*60 periods); Commercial/Industrial: 28620 (477 firms*60 periods)	Gijón, Asturias (Spain)	Linear	Residential and Commercial / Industrial
Gaudin	2005	Water Supply	Cross-section (aggregate)	Annual (1995/96)	OLS (Hausman test performed with IV/2SLS on price endogeneity "log values of the total charges for 3750-gallon and 7500-gallon monthly bills are used in addition to the other exogenous variables to instrument price" (no evidence of systematic bias found)	383 water utilities	USA	Double logarithmic (loglinear or log-log)	Residential
Hanemann and Nauges	2005	CUDARE WP - Department of Agricultural & Resource Economics, University of California, Berkeley	Panel data (household data)	Bimonthly (1988-1992)	Pooled OLS, FE, RE	3884002 (from na "unbalanced panel gathering 177,834 single-family residential customers")	Los Angeles, California (USA)	Double logarithmic (loglinear or log-log)	Residential
Martins and Fortunato	2005	Tecnologia da Agua	Cross-section (aggregate)	Annual (divided by 12 to get monthly) (2002)	2SLS, Maximum likelihood	278 municipalities	Portugal excluding Azores and Madeira	Linear	Residential
Reynaud and Thomas	2005	Revue Economique	Panel Data (aggregate)	Annual (1990-1994)	Selection model: Probit (for the choice of water utility type); RE (with BMS instruments for the direct management equation)	545 (109 municipalities*5 years)	Gironde (France)	Double logarithmic (loglinear or log-log)	Residential

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Reynaud et al.	2005	Water Resources Research	Cross-section (aggregate)	Annual (1999)	Multinomial logit (for the pricing structure choice)	899 local communities	Canada	Double logarithmic (loglinear or log-log)	Residential
Strand and Walker	2005	Environment and Development Economics	Cross-section (household data)	Monthly (the month before the survey) (1995 to 1998 according to city)	2SLS	3700 tap and nontap water users	17 cities in Central America and Venezuela: Tegucigalpa, San Pedro Sula, Santa Rosa de Copán, and Comayagua (Honduras); Managua (Nicaragua); Santa Ana, Sonsonate and San Miguel (El Salvador); Barquisimeto and Merida (Venezuela); Guatemala City, Villa Nueva, Chinautla, and Mixco (Guatemala); and Panama City and Colón (Panama)	Linear and double logarithmic	Residential
Arbués et al.	2004	Water Resources Research	Panel data (household data)	Quarterly (10 meter readings between 1996 and 1998)	GMM (Arellano-Bond estimator) and RE	15960 (1596 households* 10 quarters)	Zaragoza (Spain)	Semilogarithmic (log-lin)	Residential
Fullerton and Elías	2004	Water Resources Research	Time-series (Aggregate)	Monthly (1994-2002)	Linear Transfer Function ARIMA	108	El Paso, Texas (USA)	Linear	Municipal
Garcia and Reynaud	2004	Resource and Energy Economics	Panel data (Aggregate)	Annual	GMM	50 water utilities studied annualy 1995-98 (200 observations)	Bordeaux (France)	Double logarithmic (loglinear or log-log)	Residential and industrial aggregated

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Martínez-Espiñeira and Nauges	2004	Applied Economics	Time-Series (Aggregate)	Monthly (1991-1999)	IV, Time-series techniques (correction for AR(p) process in residuals)	108	Seville (Spain)	Stone-Geary	Residential
Mylopoulos et al.	2004	Water International	Panel data (household data)	Bimonthly (January 1994- April 2000)	FE, RE	27564 observations (1356 households in 17 municipalities and 19 bimonthy time-series observations)	Thessaloniki (Greece)	Double logarithmic (loglinear or log-log)	Residential
Taylor et al.	2004	Land Economics	Panel data (aggregate)	Monthly (1984-1985)	OLS, 2SLS	816 (34 utilities*24 months)	Colorado (USA)	Linear and double logarithmic (loglinear or log-log)	Residential
Ayadi et al.	2003	Paper presented at the 10th Annual Economic Research Forum	Panel data (aggregate)	Quarterly (1980-1996)	SURE, GLS, 3SLS, FE	408 (6 regions * 68 quarters)	Tunisia	Double logarithmic (loglinear or log-log)	Residential
Dalhuisen et al.	2003	Land Economics	Water demand studies	Studies conducted between 1963 and 2001	Meta-analysis	296 (price-elasticity); 162 (income-elasticity) from 64 studies	From around the world (several articles with different study areas)	Linear, Box-Cox	Residential
Fullerton and Nava	2003	Water Resources Research	Time-series (Aggregate)	Monthly (1998-2000)	Linear Transfer Function ARIMA	36	Chihuahua City (Mexico)	Linear	Municipal

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Garcia and Thomas	2003	Environmental and Resource Economics	Panel data (aggregate)	Annual (1998-2005)	FE	192 (48 water utilities * 4 years)	Bordeaux (France)	Linear	Municipal
Krause et al.	2003	Journal of Regulatory Economics	Panel data (Individual experimental data)	-	FGLS	114	Albuquerque, New Mexico (USA)	Linear	Residential
Martínez-Espiñeira	2003	Environmental and Resource Economics	Panel data (Aggregate)	Monthly (transformed from quarterly billing data: January 1995-June 1999)	Discrete-Continuous choice model: 2 stages: 1st stage: Discrete choice estimation of the proportion of users ending up in each block (multinomial logit); 2nd stage: continuous estimation of the unconditional demand function (panel data estimation - GLS)	Multinomial logit (1st stage): 183 observations in an unbalanced panel (4 cross-sectional groups * 54 months = 216 [if the panel was balanced and complete]). 2nd stage: 120 obsrvations in a balanced panel (4 communities * 30 months [March 1996-September 1998])	3 towns in the northwest of Spain	Linear	Residential
Nauges and Thomas	2003	Environmental and Resource Economics	Panel data (Aggregate)	Annual (1988-1993)	Dynamic Panel Data Model Techniques, GMM	696 (116 communities*6 years)	France	Double logarithmic (loglinear or log-log)	Residential
Piper	2003	Water Resources Research	Cross-section (aggregate)	Annual (1996)	3SLS	309	USA	Semilogarithmic (log-lin)	Residential
Acharya and Barbier	2002	American Journal of Agricultural Economics	Cross-section (Household data)	1995-1996	Contingent behavior, RE-GLS, SUR-FGLS	556 (purchased water); 590 (collected water) (combination of revealed preferences with contingent behavior responses from 110 households)	Hadejia–Jama'are floodplain (Nigeria)	Linear	Residential
Agthe and Billings	2002	Journal of Water Resources Planning and Management	Cross-section (aggregate data from apartment complexes)	Intra-annual (1988; 4 winter months, 4 summer months)	OLS	308	Tucson, Arizona (USA)	Linear	Residential
Hajispyrou et al.	2002	Environment and Development Economics	Cross-section (household data)	Annual (1996-1997)	OLS, IV, ML	2700	Cyprus	Quadratic logarithmic - Quadratic Almost Ideal Demand System (QUAIDS)	Residential
Ipe and Bhagwat	2002	Applied Economics	Time-series (aggregate)	Annual (1970-1997)	OLS	28	Chicago Metropolitan Area (USA)	Linear	Municipal

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Martínez-Espiñeira	2002	Environmental and Resource Economics	Panel data (aggregate)	Monthly (standardized from bimonthly or quarterly billing data; 1993-1999)	FE, 2nd step to recover coefficients of the time-invariant regressors; number of users in the municipality used to weight the observations	From 991 (summer regression) to 2792 observations (122 towns * 22,88 months was the average lenght of the time series in the unbalanced panel)	Northwest Spain	Linear	Residential
Nauges and Blundell	2002	WP - LERNA-INRA	Cross-section (household data)	Annual (1997)	Nonparametric series estimator (compared with OLS, 2SLS and ML)	1686 households from 2700 sampled households (households who face a 3-block tariff were chosen)	Cyprus	No functional form assumed in nonparametric estimation (double logarithmic used for the alternative parametric estimation techniques)	Residential
Pashardes and Hajispyrou	2002	WP - Department of Economics, University of Cyprus	Cross-section (household data)	Annual (1996/97)	Discrete-Continuous Choice model, nonlinear FIML	2468	Cyprus	Quadratic logarithmic - Quadratic Almost Ideal Demand System (QUAIDS)	Residential
Gaudin et al.	2001	Land Economics	Panel data (Aggregate)	Monthly (1981-1985)	OLS; RE; nonlinear GLS	9340 from a potential of 13260 (221 communities * 60 months)	Texas (USA)	Stone-Geary; Generalized Cobb-Douglas	Residential
Gunatilake et al.	2001	International Journal of Water Resources Development	Panel data (Household data)	Monthly (1994-1999)	GLS (Prais-Winsten transformation)	1385 from a potential of 2880 (40 households * 72 months)	Kandy municipality (Sri Lanka)	Double logarithmic (loglinear or log-log)	Residential
Higgs and Worthington	2001	Public Works Management & Policy	Cross-section (household data)	Annual (-)	OLS and IV; Logit model for the choice between two pricing methods: flat rate or volumetric	350	Brisbane (Australia)	Linear	Residential
Nauges and Reynaud	2001	Revue Economique	Panel data (Aggregate)	Annual (1989-1994)	FE	436 (109 municipalities/associations of municipalities within the Gironde department for the period 1990-1994) and 464 (116 municipalities within the Moselle department for the period 1989-1993)	2 departements: Moselle and Gironde (France)	Double logarithmic (loglinear or log-log)	Residential

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Nauges and Thomas	2000	Land Economics	Panel data (aggregate)	Annual (1988-1993)	FE	696 (116 local communities for the period 1988-1993)	East of France (France)	Double logarithmic (loglinear or log-log)	Total
Renwick and Green	2000	Journal of Environmental Economics and Management	Panel data (aggregate)	Monthly (1989-1996)	GLS, IV(2SLS) corrected for heteroskedasticity and an AR(12) process	768 (8 water agencies*96 months)	California (USA)	Double logarithmic (loglinear or log-log)	Residential
Rietveld et al.	2000	Bulletin of Indonesian Economic Studies	Cross-section (household data)	Annual (1994)	Discrete-Continuous Choice Model; Maximum Likelihood	475 households	Salatiga city, Java (Indonesia)	Double logarithmic (loglinear or log-log)	Residential
Corral et al.	1999	CUDARE WP - Department of Agricultural & Resource Economics, University of California, Berkeley	Panel data (aggregate)	Monthly (January 1982- October 1992)	Discrete-Continuous Choice model, multinomial logit for the choice of block and 2SLS	390 (3 water districts*130 months)	3 water districts in the San Francisco Bay Area (USA)	Linear	Residential
Dzisiak	1999	M. Sc. - University of Manitoba, Faculty of Graduate Studies, Department of Agricultural Economics	Panel data (aggregate)	Quarterly (1986, 89, 91 and 92)	OLS	206 (from an unbalanced panel of 25 communities and 16 quarters)	Alberta, Manitoba and Saskatchewan provinces (Canada)	Linear; double logarithmic (loglinear or log-log)	Residential
Höglund	1999	Water Resources Research	Panel data (Aggregate)	Annual (1980-1992)	Panel data techniques (static and dynamic), OLS, GLS, 2SLS	282 communities (out of 286) studied annualy 1980-1992 (3190 observations because of missing data [282*13 = 3666] for static models and 1485 observations for dynamic models [135*11])	Sweden	Linear	Residential
Merrifield and Collinge	1999	Public Works Management & Policy	Cross-section (aggregate)	Annual (1991)	OLS	30	San Antonio, Texas (USA)	Linear, double logarithmic (loglinear or log-log) and Box-Cox	Residential
Pint	1999	Land Economics	Panel data (household data)	Bimonthly (1982-1992)	Panel Data Techniques (Fixed-effects model), Maximum Likelihood, Discrete/continuous choice model - choice of block (Probit)	599 single-family households, studied bimonthly 1/1982-7/1992 (37737 observations [599*63])	Alameda County Water District (ACWD) - Fremont, Newark and Union City, California (USA)	Linear	Residential
Renzetti	1999	Canadian Journal of Economics	Cross-section (aggregate)	Annual (1991)	OLS	77	Ontario (Canada)	Double logarithmic (loglinear or log-log)	Residential and nonresidential

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Billings and Agthe	1998	Journal of Water Resources Planning and Management	Time Series (Aggregate)	Monthly (1974-1988)	IV, state-space modelling	84	Tucson, Arizona (USA)	Linear	Residential
David and Inocencio	1998	WP - Economy and Environment Program for Southeast Asia	Cross-section (household data)	Monthly (1995)	OLS, 2SLS	506	Metro Manila (Philippines)	Linear and double logarithmic (loglinear or log-log)	Residential (connected and non-connected)
Largo et al.	1998	Philippine Institute for Development Studies Discussion Paper	Cross-section (household data)	Monthly (-)	2SLS	466	Metro Cebu (Philippines)	Linear and double logarithmic (loglinear or log-log)	Residential (connected and non-connected)
Mattos	1998	Pesquisa e Planejamento Econômico	Time Series (Aggregate)	Monthly (1993-1996)	OLS, 2SLS	48	Piracicaba, São Paulo (Brazil)	Linear	Residential
Renwick and Archibald	1998	Land Economics	Panel data (household data)	Monthly (1985-1990)	IV, 2SLS, Probit and ML (for the technology adoption equations)	8568 (119 households*72 months)	Santa Barbara, California (USA)	Linear	Residential
Agthe and Billings	1997	Journal of Water Supply Research and Technology - AQUA	Cross-section (household data)	Monthly (January 1977-December 1981 and January 1986-December 1988)	IV	106560 (1110 households * 96 months)	Tucson, Arizona (USA)	Semilogarithmic (log-lin)	Residential
Dandy et al.	1997	Land Economics	Panel data (household data)	Intra-annual (6 months periods) (1978/79-1991/92)	OLS	2710 (average period for the households = 8 1/2 years; 320 sampled households)	Adelaide, South Australia (Australia)	Linear	Residential
Espey et al.	1997	Water Resources Research	Water demand studies.	Studies published between 1967 and 1993.	Meta-Analysis (OLS)	124 estimations from 24 journal articles	USA	Linear, Semilogarithmic and Box-Cox	Residential
Malla and Gopalakrishnan	1997	International Journal of Water Resources Development	Panel data (data on multi-unit residences)	Monthly (August 1991-December 1994)	OLS and GLS	450 (15 multi-dwelling residential units * 30months)	Honolulu, Hawaii (USA)	Linear	Residential

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Saleth and Dinar	1997	Technical Paper - World Bank	Cross-section (household data)	Annual (1991-1992)	OLS	858	Hyderabad City, Andhra Pradesh (India)	Double logarithmic (loglinear or log-log)	Residential
Barkatullah	1996	WP - University of Sydney, Department of Economics	Panel data (household data)	Quarterly (1990-1994)	OLS, IV, ML and correction for AR(1) autocorrelation	17040 (1065 households*16 quarters	Sydney Metropolitan and Wollongong areas, New South Wales (Australia)	Double logarithmic (loglinear or log-log)	Residential
Dziegielewski	1996	Chapter in the book Hall (ed.) "Marginal Cost Rate Design and Wholesale Water Markets"	Water demand studies	-	Meta-analysis (OLS)	160 estimations from 38 studies	USA	Linear	Residential
Hansen	1996	Land Economics	Time-series (Aggregate)	Annual (1981-1990)	OLS (adjusted Durbin-Watson and Durbin tests showed no serial correlation)	30 (3 types of dwellings * 3 years)	Copenhagen (Denmark)	Linear, semilogarithmic (log-lin)	Residential
Andrade et al.	1995	Pesquisa e Planejamento Econômico	Cross-section (household data)	Monthly (March, 1986)	2SLS	5417	Paraná (Brazil)	Linear	Residential
Hewitt and Hanemann	1995	Land Economics	Panel data (Household data)	Monthly (Summer months, June-August, 1981-1985)	OLS, IV, 2SLS, Discrete/Continuous choice model - choice of block (Probit)	1703	Denton, Texas (USA)	Double logarithmic (loglinear or log-log)	Residential

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Bachrach and Vaughan	1994	WP - Inter-American Development Bank, Productive Sectors and Environment Subdepartment, Environment Protection Division	Cross-section (household data)	Annual (1987)	OLS, IV	685	34 rural localities in Argentina	Linear	Residential
Crane	1994	World Development	Cross-section (Household data)	Monthly (1991)	OLS	291	Jakarta (Indonesia)	Double logarithmic (loglinear or log-log)	Residential (water vendors and public taps [hydrants])
Walters and Young	1994	Colorado Water Resources Research Institute Completion Report	Panel data (aggregate)	Annual (1984-1985)	OLS	66 (33 utilities*2 years)	Colorado (USA)	Linear and semilogarithmic (log-lin)	Residential
Boistard	1993	Revue des Sciences de l'Eau (Journal of Water Science)	Panel data (aggregate)	Annual (1975, 1980, 1985, 1990)	OLS	8 classes aggregated from 1336 water utilities used in cross-section regressions in separate years (1975-1980). 2 groups aggregated from a panel of 500 utilities (1975-1990) used to calculated arc-elasticities	France	Linear and double logarithmic (loglinear or log-log)	Residential
Nieswiadomy and Cobb	1993	Contemporary Policy Issues	Cross-section (Aggregate)	Monthly (1984)	OLS, Logit model for tariff selection	229	USA	Double logarithmic (loglinear or log-log)	Residential
Point	1993	Revue Economique	Cross-section (aggregate)	Annual (1975)	OLS	62	Gironde (France)	Semilogarithmic (log-lin)	Municipal
Lyman	1992	Water Resources Research	Panel data (household data)	Bimonthly (1893-1987)	OLS	656 (30 households * 30 periods of two months each - lagging - errors in observations)	Moscow, Idaho (USA)	Double logarithmic (loglinear or log-log)	Residential
Martin and Wilder	1992	Public Finance Quarterly	Panel data (household data)	Monthly (July 1980-June 1981)	OLS, IV (2SLS)	About 83000 observations from approximately 19000 accounts (after deleting observations with missing values)	Columbia, South Carolina (USA)	Double logarithmic (loglinear or log-log)	Residential
Nieswiadomy	1992	Water Resources Research	Cross-section (Aggregate)	Monthly (1984)	OLS, IV, 2SLS (Hausman test did not reject endogeneity of MP and conservation and educational programs)	430	Different regressions for North Central, Northeast, South and West (USA)	Double logarithmic (loglinear or log-log) (after Box-Cox test)	Residential

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Renzetti	1992	Journal of Environmental Economics and Management	Time-Series	Quaterly (1975-1986)	IV (2SLS)	33 (industrial); ? (residential)	Vancouver (Canada)	Translog	Residential and industrial
Stevens et al.	1992	Water Resources Bulletin	Cross-section (Aggregate)	Annual (1985)	OLS, IV(2SLS)	85 communities	Massachussets (USA)	Linear	Residential
Woo	1992	Water Resources Research	Time-series (aggregate)	Monthly (1973-1984)	Box-Cox estimator, considering AR(1) error. Hausman test does not reject AP exogeneity	144	Hong Kong (China; UK at the time of study)	Box-Cox	Municipal
Griffin and Chang	1991	Western Journal of Agricultural Economics	Panel data (aggregate)	Monthly (1981-1985)	Pooled OLS	1105 (221 communities*5 years)	Texas (USA)	Linear, double logarithmic (loglinear or log-log), generalized Cobb-Douglas, translog, aumented Fourier	Residential and commercial
Nieswiadomy and Molina	1991	Land Economics	Panel data (Household data)	Monthly (1976-1985)	OLS, IV (2SLS) (Hausman test performed to demonstrate endogeneity)	5454 observations (101 households, studied monthly for 54 periods, the summer months: May to October, 1976-1980 [DBT], June to September 1981-1983, May-October 1984-1985 [IBT])	Denton, Texas (USA)	Double logarithmic (loglinear or log-log)	Residential
Rizaiza	1991	Water Resources Research	Cross-section (household data)	Annual (1985)	OLS	400	Jeddah, Makkah, Madina and Taif, Western Region (Saudi Arabia)	Double logarithmic (loglinear or log-log)	Residential
Schneider and Whitlatch	1991	Journal of Water Resources Planning and Management	Panel data (aggregate)	Annual (1959-1977)	Panel data techniques (GLS with and without partial adjustment, with and without time series and cross section dummy variables)	108-234 (6-13 communities * 18 years)	City of Columbus, Ohio (USA)	Linear	Residential, commercial, industrial, government, school and total.

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Billings	1990	Journal of Water Resources Planning and Management	Time-series (aggregate)	Monthly (January 1974-December 1980)	OLS	84	Tucson, Arizona (USA)	Linear and double logarithmic (loglinear or log-log); Dynamic Koyck	Residential
Griffin and Chang	1990	Water Resources Research	Panel data (Aggregate)	Monthly (January 1983-December 1985)	Pooled OLS	1031 observations from a potential of 1080 (30 communities * 36 months)	Texas (USA)	Linear	Residential and commercial
Miaou	1990	Water Resources Research	Time-series	Annual (1961-1980) from Cochran and Cotton, 1985 and Annual (1946-1971), from Young, 1973	Stepwise regression and ARIMA model for error	20 (Cochran and Cotton, 1985) and 26 (Young, 1973)	Tucson, Arizona and Oklahoma City and Tulsa, Oklahoma (USA)	Linear and double logarithmic (loglinear or log-log)	Municipal
Mu et al.	1990	Water Resources Research	Cross-section (household data)	Daily	Discrete choice model for the type of water access; OLS for the demand equation	69	Ukunda, Mombasa (Kenya)	Linear, double logarithmic (loglinear or log-log) and semiligarithmic (log-lin and lin-log)	Residential (non-tap)
Billings and Day	1989	Journal of the American Water Works Association	Panel data (aggregate)	Monthly (1974-1980)	OLS	984 (from 11 water districts)	Tucson, Arizona (USA)	Linear	Residential
Moncur	1989	Water Resources Bulletin	Time-series (aggregate)	Monthly (1975-86)	ARIMA	95	Honolulu, Hawaii (USA)	Linear	Municipal
Nieswiadomy and Molina	1989	Land Economics	Panel data (Household data)	Monthly (summer months: May-October 1976-1980, June-September 1981-1983, May-October 1984-1985)	OLS, IV, 2SLS (Hausman test performed to demonstrate endogeneity)	5454 observations (101 households, studied monthly for 54 periods, the summer months: May to October, 1976-1980 [DBT], June to September 1981-1983, May-October 1984-1985 [IBT])	Denton, Texas (USA)	Linear	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Weber	1989	Water Resources Bulletin	Panel data (aggregate)	Monthly (January 1981-December 1987)	OLS	1008 (12 districts*84 months)	Oakland, California (USA)	Linear	Residential
Wilson	1989	Water Resources Research	Cross-section (Aggregate)	Annual (1964-1965)	OLS	12	12 suburban areas near Oakland and San Diego, California and Forth Worth, Texas (USA)	Linear	Residential
Nieswiadomy and Molina	1988	Growth and Change	Panel data (household data)	Monthly (Summer months, 1981-1985; June-September 1981-1983, May-October, 1984-1985)	OLS, IV, 2SLS	2702 (from 104 customers and the summer months of 5 years)	Denton, Texas (USA)	Linear	Residential
Palencia	1988	Water Resources Bulletin	Time Series (Aggregate)	Annual (1970-1981)	OLS (corrected from 1st degree of autocorrelation)	11	Manila (Philippines)	Linear	Residential
Thomas and Syme	1988	Water Resources Research	Time-series (aggregate) and cross-section, household data for CV	Annual (1957/58-1985/86 for TS), 1982 (CV)	OLS (for time-series data) and Contingent Valuation	28 (TS); 312 (CV)	Perth Metropolitan Area, Western Australia (Australia)	Linear	Residential
Agthe and Billings	1987	American Journal of Economics and Sociology	Panel data (household data)	Monthly (1974-1981)	IV, Simultaneous equations	2673 to 7149 (depending on the income group)	Tucson, Arizona (USA)	Linear	Residential
Billings	1987	Water Resources Bulletin	Time-series (Aggregate)	Monthly (January 1974-December 1980)	OLS, IV, censored sample technique	84 (time-series); 1008 (panel: 12 districts*84 months)	Tucson, Arizona (USA)	Linear	Residential
Frerichs et al.	1987	University of Minnesota, Department of Applied Economics, Economic Report	Cross-section (aggregate)	Annual (1986)	OLS	92	Minnesota (USA)	Linear and double logarithmic (loglinear or log-log)	Residential

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Moncur	1987	Water Resources Research	Panel data (household data)	Bimonthly (1974-1981)	Panel data techniques	53802 (1281 households*42 bimonthly billing periods)	City and County of Honolulu, Hawaii (USA)	Linear	Residential
Schefter	1987	Land Economics	Cross-section (aggregate)	Annual (1979)	OLS	19 communities	Wisconsin (USA)	Linear	Residential
Agthe et al.	1986	Water Resources Research	Time-series (Aggregate)	Monthly (January 1974-December 1980)	OLS, IV, simultaneous equations	84	Tucson, Arizona (USA)	Linear	Residential
Chicoine and Ramamurthy	1986	Land Economics	Panel data (Household data)	Monthly (1982)	Pooled OLS	681 (1200 potential observations [12 monthly observations in 1982 *100 sampled customers], but consumptions in the 1st block and where uniform prices apply were discarded)	Illinois (rural areas) (USA)	Linear	Residential
Chicoine et al.	1986	Water Resources Research	Panel data (Household data)	Monthly (1982)	OLS, IV, 2SLS, 3SLS, Simultaneous equations	641 (648 potential observations: 54 monthly observations in 1982 * 54 households; consumptions in the 1st block were discarded)	Illinois (rural areas) (USA)	Linear	Residential
Deller et al.	1986	Southern Economic Journal	Panel data (Household data)	Monthly (1982)	OLS, IV (2SLS)	641 (648 potential observations [12 monthly observations in 1982 *54 sampled customers], but consumptions in the 1st block are discarded adding to missing data andobservations discarded for measurement problems)	Illinois (rural areas) (USA)	Linear	Residential
Martin and Thomas	1986	Water Resources Research	Cross-section (household data)	Annual (1978/79 or 1981/82)	OLS	5	Perth, Western Australia; Coober Peddy, South Australia (Australia); Tucson and Phoenix, Arizona (USA); Kuwait	Double logarithmic (loglinear or log-log)	Residential
Williams and Suh	1986	Applied Economics	Cross-section (Aggregate)	Annual (1976)	OLS	86	USA	Linear and double logarithmic (loglinear or log-log) (logarithmic chosen based on R2)	Residential, commercial and industrial
Al-Qunaibet and Johnston	1985	Water Resources Research	Time-series (Aggregate)	Monthly (January 1973-December 1981)	ML	96	Kuwait	Linear, double logarithmic (loglinear or log-log), Semilogarithmic (lin-log and log-lin) and Stone-Geary	Municipal
Cochran and Cotton	1985	Water Resources Research	Time-series (Aggregate data)	Annual (1961-1980)	OLS	20	Oklahoma City and Tulsa, Oklahoma (USA)	Linear and double logarithmic (loglinear or log-log)	Municipal

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Schefter and David	1985	Land Economics	Cross-section (aggregate)	Annual (1979)	OLS	131	Wisconsin (USA)	Linear	Residential
Jones and Morris	1984	Water Resources Research	Cross-section (household data)	Annual (1976)	IV	326	Metropolitan Area of Denver, Colorado (USA)	Linear, double logarithmic (loglinear or log-log), Semilogarithmic (log-lin)	Residential
Young et al.	1983	Water Resources Bulletin	Panel data (Household data)	Quarterly (1974-1977)	RE	8720 (545 households*16 quarters)	Washington D.C. (USA)	Linear	Residential
Billings	1982	Land Economics	Time Series (Aggregate)	Monthly (January 1974-September 1977)	IV	45	Tucson, Arizona (USA)	Linear; double logarithmic (log-linear or log-log)	Residential
Hanke and de Maré	1982	Water Resources Bulletin	Panel data (household data)	Semiannualy (last period of 1971 to first period of 1978)	OLS	959 observations in a potential of 966 (69 households, studied semi-annualy, over 14 time periods)	Malmö (Suécia)	Linear	Residential
Howe	1982	Water Resources Research	Cross-section (Aggregate)	Intra-Annual (1963-1965)	OLS	21	USA	Linear	Residential
Ford and Ziegler	1981	The Annals of Regional Science	Cross-section (household data)	-	OLS	1770	Arkansas (USA)	Semilogarithmic (log-lin)	Residential
Foster and Beattie	1981	Land Economics	Cross-section (aggregate)	Annual (1960)	OLS	218 cities	USA	Semilogarithmic (log-lin)	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Agthe and Billings	1980	Water Resources Research	Time Series (Aggregate)	Monthly (-)	OLS	45	Tucson, Arizona (USA)	Static: linear, Fisher-Kaysen; Dynamic: Koyck distributed lag model, Bergstrom model or flow adjustment model (linear and logarithmic)	Residential
Ben-zvi	1980	Report - U.S. Army Corps of Engineers	Cross-section (aggregate: nonindustrial; firm data: industrial)	Monthly (1978)	OLS	20 (nonindustrial); 84 (industrial plants)	Red River Basin, Tulsa, Oklahoma (USA)	Double logarithmic (loglinear or log-log)	Industrial and non-industrial
Billings and Agthe	1980	Land Economics	Time Series (Aggregate)	Monthly (January 1974-September 1977)	OLS	45	Tucson, Arizona (USA)	Linear; double logarithmic (log-linear or log-log)	Residential
Carver and Boland	1980	Water Resources Research	Panel data (Aggregate)	Monthly (1969-1974)	OLS and LSDV (FE)	376 (nonseasonal); 373 (seasonal) (from unbalanced panels of 13 utilities * 30 months)	Washington D. C. (USA)	Linear	Municipal
Cassuto and Ryan	1979	Water Resources Bulletin	Panel data (aggregate)	Monthly (1970-1975)	OLS	19008 (264 census tracts*72 months)	Oakland, California (USA)	Linear and double logarithmic (loglinear or log-log)	Residential
Colander and Haltiwanger	1979	Water Resources Research	Time-series (Aggregate)	Annual (1946-1971)	OLS (corrected from 1st degree of autocorrelation)	26	Tucson, Arizona (USA)	Double logarithmic (loglinear or log-log)	Residential
Danielson	1979	Water Resources Research	Panel data (Household data)	Monthly (May 1969-December 1974)	OLS	17748 (261 households*68 months)	Raleigh, North Carolina (USA)	Double logarithmic (loglinear or log-log)	Residential
Foster and Beattie	1979	Land Economics	Cross-section (aggregate)	Annual (1960)	OLS	218 cities	USA	Semilogarithmic (log-lin)	Residential
Camp	1978	Journal of the American Water Works Association	Cross-section (Household data)	Monthly (-)	OLS	288	Northern Mississipi (USA)	Linear, double logarithmic (loglinear or log-log) and semiligarithmic (log-lin and lin-log)	Residential
Gibbs	1978	Water Resources Research	Panel data (Household data)	Quarterly (1973)	OLS	1412 (355 households*4 quarters)	Miami, Florida (USA)	Semilogarithmic (log-lin)	Residential

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Katzman	1977	Water Resources Bulletin	Cross-section and panel data (household data)	Quarterly (1972) and bimonthly (May 1970-November 1975)	OLS	1400 (for quarterly croos-section)	Penang Island (Malaysia)	Linear	Residential
Clark	1976	Journal of the Environmental Engineering Division	Cross-section (aggregate)	Annual (-)	OLS	22	Cincinnati, Ohio (USA)	Linear, double logarithmic (loglinear or log-log), inverse, exponential, inverse semilog	Municipal
Grunewald et al.	1976	Water Resources Bulletin	Cross-section (aggregate)	Annual (1972)	OLS	150 rural water districts	Kentucky (USA)	Linear; double logarithmic (loglinear or log-log)	Residential
Morgan and Smolen	1976	Water Resources Bulletin	Cross-section (aggregate)	Monthly (-)	OLS	396 (33 cities * 12 months)	Southern California (USA)	Linear	Municipal
Andrews and Gibbs	1975	Southern Journal of Agricultural Economics	Panel data (Household data)	Quarterly (1973)	OLS	1420 (4 quarters * 355 sampled households)	Dade County, Metropolitan Miami, Florida (USA)	Semilogarithmic (log-lin)	Residential
Attanasi et al.	1975	Report - U.S. Department of Interior	Panel data (Aggregate)	Annual (1960-1971)	OLS and RE	143 (13 municipalites*11 years)	San Juan, Puerto Rico (USA)	Linear	Residential, commercial and industrial
Batchelor	1975	Land Economics	Cross-Section (household data)	Annual (1968)	GLS	698	Malvern, Worcestershire (UK)	Linear	Residential
Darr et al.	1975	Water Resources Research	Cross-section (Household data)	Annual (1970/1971)	OLS	1892	Jerusalen, Tel Aviv, Haifa and Beersheva (Israel)	Linear and double logarithmic (Log-linear or log-lo-log)	Residential
Hogarty and MacKay	1975	Water Resources Research	Panel data (household data)	Quarterly (1971(4)-1973(4))	OLS	1080 (120 households * 9 quarters)	Blacksburg, Virgina (USA)	Linear	Residential
Morgan	1974	Water Resources Bulletin	Time-series (individual data)	Bimonthly (1968-1971)	OLS	816 (34 households * 24 bimonthly billing periods) [31 for the 2nd regression, 30 billing periods 1967-1972 (February)]	Goleta County Water District, Santa Barbara, California (USA)	Linear	Municipal

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Grima	1973	Water Resources Bulletin	Cross-section (household data)	Intra-annual (-)	OLS	102	Toronto (Canada)	Double logarithmic (loglinear or log-log)	Residential
Morgan	1973	Water Resources Research	Cross-section (household data)	Bimonthly (-)	OLS	92	Santa Barbara County, California (USA)	Linear and double logarithmic (Log-linear or log-lo-log)	Residential
Young	1973	Water Resources Research	Time-series (Aggregate)	Annual (1946-1971)	OLS	26	Tucson, Arizona (USA)	Linear; double logarithmic (loglinear or log-log)	Municipal
Wong	1972	Land Economics	Time-series and Cross-section (aggregate)	Annual (1951-1961)	OLS	11 (time-series), 103 (cross section; stratified into 4-community size groups with 15 to 40 observations each)	Chicago, Northeastern Illinois (USA)	Double logarithmic (loglinear or log-log)	Municipal
Hanke and Davis	1971	Journal of the American Water Works Association	Cross-section (aggregate)	Intra-annually (1969)	OLS	-	Washington D.C., District of Columbia, Fairfax County, Virginia and Maryland (USA)	Double logarithmic (loglinear or log-log)	Residential and Commercial/ industrial
Hanke	1970	Water Resources Research	Time-series (Aggregate)	Monthly (1955-1968)	OLS	168	Boulder, Colorado (USA)	Linear	Residential
Turnovsky	1969	Water Resources Research	Cross-section (Aggregate)	Annual (separate regressions for 1962 and 1965)	OLS	19	Massachussets (USA)	Linear	Residential and industrial/services
Meroz	1968	WP - International Bank for Reconstruction and Development, Economics Department	Cross-section (Aggregate)	Annual (1957 to 1965, depending on observation)	OLS	38	Africa, Asia, Latin America	Linear; double logarithmic (loglinear or log-log)	Residential and other
Conley	1967	The Annals of Regional Science	Cross-section (Aggregate)	Annual (1955)	OLS	24	Southern California (USA)	Double logarithmic (loglinear or log-log)	Residential
Howe and Linaweaver	1967	Water Resources Research	Cross-section (Aggregate)	Intra-Annual (1963-1965)	OLS	39	USA	Linear; double logarithmic (loglinear or log-log)	Residential
Bain et al.	1966	Book published by Johns Hopkins Press	Cross-section (Aggregate)	Annual (1955)	OLS	41	Northern California (USA)	Double logarithmic (loglinear or log-log)	Municipal
Flack	1965	PhD thesis - Stanford University	Cross-section (Aggregate)	Annual (-)	OLS	54	USA	Linear	Municipal

Authors	Year of publication	Where Published	Type of data	Periodicity	Econometric method	Number of observations	Study area	Functional form	Type of demand
Gardner and Schick	1964	Bulletin - Agricultural Experiment Station, Utah State University	Cross-section (Aggregate)	Annual (-)	OLS	43	Utah (USA)	Linear; double logarithmic (loglinear or log-log)	Municipal
Gottlieb	1963	Land Economics	Cross-section (Aggregate)	Annual (1957)	OLS	70 (12 Illinois, 24 Kansas, 34 USA)	Kansas and Illinois (USA)	Double logarithmic (loglinear or log-log)	Municipal
Headley	1963	Land Economics	Time-series and Cross-section (aggregate)	Annual (1950-1959)	OLS	10 (time-series); 14 (cross-section)	San Francisco-Oakland Metropolitan Area (USA)	Linear, semilogarithmic (log-lin)	Residential and Commercial
Fourt	1958	Unpublished paper - Agricultural Economics Seminar, University of Chicago	Cross-section (Aggregate)	Annual (1955)	OLS	34	Southern California (USA)	Double logarithmic (loglinear or log-log)	Municipal
Seidel and Baumann	1957	Journal of the American Water Works Association	Cross-section (Aggregate)	Annual (1955)	OLS	111	USA	Linear	Municipal
Larson and Hudson	1951	Journal of the American Water Works Association	Cross-section (Aggregate)	Annual (1948)	OLS	15	Illinois (USA)	Linear	Residential
Metcalf	1926	Journal of the American Water Works Association	Cross-section (Aggregate)	5 year-averages (1920-1924)	OLS	29	USA	-	Municipal

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Bartczak et al.	2009	Daily per capita water consumption	X (including wastewater charges)	Average net income per capita	X	-	Year dummies
Diakité et al.	2009	1st stage: proportion of users per block; 2nd stage: average water use per account per year	2nd stage: average/weighted AP (the weights are proportion of users per block)	X	-	-	Unpaid volumes per household; % of subsidized new customers; access to water/1000 individuals; network rate of return; number of customers
Garcia-Valiñas et al.	2009	Average consumption per household	AP	Average taxable income	X	-	Regional indicator; Share of apartments in the total population of residences; dummies for urban or touristic zones; temporal dummies)
Olmstead	2009	Average daily water demand in each of the two week periods (arid and wet season)	MP (Instruments used for MP in the IV model: twelve instruments representing the "marginal price of consuming thousand-gallon increments of water — as many increments as the price variation in the data will allow: 1, 2, 3, 5, 6, 8, 10, 20, 30, 40, 50, and 75 thousand gallons"; "monthly fixed fees charged to water consumers"; "exogenous covariates from the water demand model")	Virtual income (difference between the unadjusted income and the difference variable from the Taylor-Nordin specification)	X	maximum daily temperature, the moisture requirement of lawns (evapotranspiration, less 0.6*measured precipitation), dummy variable set equal to one during the outdoor watering season.	Lot size, square footage of homes, home age, number of bathrooms, dummy variable for evaporative air cooling (which substitutes water for electricity in air conditioning). Dummy variables that represent the seven urban areas in the data
Ruijs	2009	per capita consumption of water (m3/month)	MP (3rd block price) and difference (Taylor-Nordin specification)	Per capita income	-	average temperature; precipitation; lagged precipitation	Dummy for whether rationing occurred; lagged consumption
Schleich	2009	Average water use per capita per day	AP (including sewage tariffs)	Average net income of private households per capita	X	Rainfall (average number of days with rainfall >1mm in spring and summer months: April-September) and average temperature during the spring and summer months	Average population age; share of households served with wells; regional dummy variables; share of single-family households
Schleich and Hillenbrand	2009	Average water use per capita per day	AP (including sewage tariffs)	Average net income of private households per capita	X	precipitation (average number of days with precipitation >1mm in spring and summer months: April-September) and average temperature during the spring and summer months	Average population age; share of households served with wells; regional dummy variables; share of single-family households
Arbués-Gracia et al.	2008	Average daily water consumption in the quarter (in logs)	MP (t-2)	Registered real estate value of the property	Different regressions are performed for each household size	Dummy variable for temperature (1 if greater than 18.ºC, 0 otherwise)	Common central heating (common water use)
Azomahou	2008	Average annual water consumption per household (includes water losses in the network)	AP	X (Annual average disposable income divided by two)	-	precipitation, Mean temperature	AP of electricity; % of population with 19 years or less of age; household density (households/hectare); proportion of employess; proportion of unemployed; index of equipment (showers + toilets + bath-tubs / population * 100)

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Basani et al.	2008	Monthly household water consumption	MP; connection fee (selection model)	Household expenditure	X	-	Location dummies; connection dummy; dummies for house equipment ownership; education level dummies; age of the head of household; time that the head of household has lived in the house; % household members earning income; dummies for customer satisfaction with water quality and service reliability; dummies for several water uses; dummy for shared connections and for water clearity
Bell and Griffin	2008	Daily per capita water supplied	MP and AP (including sewerage charges)	Monthly personal income	-	Average minimum and maximum temperature and days in month with no precipitation	-
Cheesman et al.	2008	Monthly household water consumption (separate regressions for households using only a private connection and using both a private connection and a well)	X	Household income	X	-	Dummy for knowledge of the water price (alone and interacted with the price), farming households, households running a business and use of storage tank. Storage capacity
Frondel and Messner	2008	Household water consumption	X (including sewer charges)	Household income	-	Temperature and precipitation	Age of survey respondent. Dummies for: sex of respondent; house-type (one family); dishwasher; swimming pool; high outdoor water consumption; if respondent stated that saving water conserves the environment; if respondent stated that saving water saves money; respondent has correctly indicated the broad range of prices
Kenney et al.	2008	Household consumption per billing period	AP (instrumented)	Median household income	X	Total precipitation and average daily maximum temperature	Dummy variable for: the existence of use restrictions during the billing period (also interacted with AP); household's participation in the outdoor rebate program for the implementation of water efficient technologies; purchase of a water smart reader; irrigation season (May-October); Christmas of Thanksgiving during the billing period. Length of the billing period; Median age of homeowner; % of homes owner occupied; % of homes built prior to 1970; % of homes built after 1991; median number of bedrooms; dummy variable for the existence of IBT
Miyawaki et al.	2008	Total water consumed	X (includes sewage charge)	X (virtual income)	X	-	Number of rooms in house/apartment; total floor space of house/apartment; lagged dependent variable on one of the models
Nataraj and Hanemann	2008	Household water consumption (1 observation = 2 months)	MP	X (used to test the difference between control and treatment groups)	X (used to test the difference between control and treatment groups)	Maximum temperature, evapotranspiration minus precipitation	Treatment dummy; dummy variable for 1995; Variables used to test the difference between control and treatment groups: average age of residents; house age; number of rooms and bedrooms; housing density ina given area as a proxy for lot size; population density and % of owned houses in a given area

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Nauges and Berg	2008	Piped and non-piped household water demand	MP and AP (instrumented by household location dummies); time cost for getting water from non-piped sources	Monthly household income	X	-	Number of rooms; dummy for the use of a storage tank; years of education of the head of household; regional dummies; number of hours of piped water availability; dummy variables regarding taste, reliability, and safety of water from private wells, use of an electric pump and household's ethnicity (for the non-piped water demand equation)
Reynaud	2008	Water consumption per day (different regressions for peak and off-peak)	AP. Unit price (including taxes) per cubic meter for an annual water consumption equal to 120 cubic meter (unit price is obtained by dividing the total bill by the water consumption)	X (representative household's income)	X	Values for summer and fall for the following variables: daily minimal temperature; daily maximal temperature; daily solar radiation; Penman's PET (potential evapotranspiration); daily rain	number of consumption units per household; dummy for nitrate vulnerable area; dummy if tourist area; population density; share of water from groundwater sources; share of water from surface sources; share of seasonal population; ratio of domestic to other water users; share of permanent housing; share of collective housing; share of rivers classified as bad quality within a given local community
Ruijs et al.	2008	per capita consumption of water (m3/month)	MP and difference, and AP (instrumented from the block prices)	Per capita income	-	average temperature; precipitation; lagged precipitation	Dummy for whether rationing occurred; time trend; lagged consumption
Statzu and Strazzera	2008	Average annual water consumption per household	AP	Average household taxable income	X	Summer evapotranspiration rate	Town's tourist specialization level; number of hours of regular water distribution; % population not in the labour force; % of home owners; % of dwellings that have not been refurbished in the period; town altitude; dummies for different utilities; year dummies
Strong and Smith	2008	Average monthly household water consumption	MP	X	-	Temperature and precipitation	% of houses with pools; total number of lots in the service area, number of rental units
Xayavong et al.	2008	Household water consumption	MP and difference (weighted means using proportions of users per block estimated from climate data, demographic factors and housing characteristics)	Virtual income and real income	X	Summer (November-April) precipitation and summer cooling-degree-days	% of home owners and renters; % people >65 and <19 years; bores/user accounts; average lot size
Babel et al.	2007	Total daily domestic water use	AP (average water tariff rate after minimum allowance of water supply (10m^3/month))	Per capita GDP (current prices) (dropped because of multicollinearity)	Average household size (dropped because of multicollinearity)	Average annual temperature (dropped because it was not significant); annual precipitation	Number of connections; population (dropped because of multicollinearity); ratio of the total population to the university students; number of households (dropped because of multicollinearity)
Dahan and Nisan	2007	Annual household water consumption	MP (highest price paid during the year) and difference (Taylor-Nordin specification)	Dummy for households below poverty line	Dummy variables for the several household sizes	-	Apartment size; lawn size; number of apartments in the building; regional dummy variable; dummies for tax reliefs
Fullerton et al.	2007	Per customer water consumption (a regression for the number of customers is also performed)	AP (including sewage charges)	-	-	Precipitation, average temperature	Monthly maquiladora employment; National industrial production index for Mexico
Grafton and Kompas	2007	Aggregate daily water demand	X	-	X	Daily temperature; daily precipitation	Dummy variable to account for reductions in demand following the introduction of water restrictions
Grafton and Ward	2007	Aggregate daily water demand	X	-	-	Daily precipitation (current and lagged); maximum daily temperature (current and lagged)	Water restrictions - two dummy variables (from November 1994 to October 1996, and from October 2003 to the end of the sampling period)

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Mansur and Olmstead	2007	Daily household water demand (total, indoor and outdoor)	MP	Virtual income (income + difference)	X	Dummy variable for season (arid vs. wet); maximum daily temperature; evapotranspiration less effective (0.6) precipitation	Household lot size; size and age of homes; number of bathrooms; presence of evaporative cooling; regional dummies
Martínez-Espiñeira	2007	Average per capita monthly domestic water use.	MP and difference (Taylor-Nordin specification) (difference used to calculate virtual income; see income)	Virtual income (difference between the average salaries and the difference variable from the Taylor-Nordin specification)	-	Precipitation (monthly); Temperature (average of daily maximum temperatures in the month)	Water restrictions ("number of daily hours [weighted by the number of days in a month] of supply restrictions applied as part of the emergency control measures during the worst drought periods."); dummy variable for temporary outdoor-use bans; dummy variable for periods when "water conservation information campaigns were being applied during the drought"; dummy variable for the months of May, June, July and August
Martins and Fortunato	2007	monthly water demanded per typical (representative) household in a local community (standardized into monthly equivalents)	MP and difference (Taylor-Nordin specification) (instrumentes from a linear approximation to the total water bill) (sewage rates considered with water prices when applicable)	automatic teller machines withdrawals per capita (deflated and used as a proxy for the income variable)	X	Precipitation (Normal monthly precipitation) and temperature (Normal maximum monthly air temperature) (from AGRIBASE) (The values used for these variables are their normal values per month, computed as historical (long-term) averages for a period of 30 years).	Dummy variable, which takes the value 1 in the case that only one block price applies to every cubic metre consumed and the value 0 if several block prices are applied; percentage of people over 65
Musolesi and Nosvelli	2007	Average annual household water consumption	AP	Average per capita income	X	-	% of population > 65 years of age; lagged consumption; % of commercial entreprises
Nauges and Strand	2007	1st step: selected water source (private tap; public weel; truck; public tap is the comparison group); 2nd step: total water consumption (including free water) per capita per month	2nd step: Total costs per cubic meter (marginal price + monetized hauling cost)	X (1st and 2nd step)	1st step: Number of households in residence; 2nd step: household size	-	1st step: Lot size; constructed area; access to electricity; "interviewee reads and writes"; number of children less than five; 2nd step: lot size; money saving due to having access to free water

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Olmstead et al.	2007	Daily household water demand	MP	X	X	Evapotranspiration less effective precipitation; Maximum daily temperature; dummy variable set equal to one during the arid (peak outdoor watering) season	Lot size; Square footage of homes; number of bathrooms; Home age; Dummy variable for price structure (IBT vs UP); Evaporative cooling in air conditioning (uses water instead of electricity); Dummy variable for city specific effect
Yoo	2007	Natural logarithm of the household's monthly tap water demand	AP (natural logarithm of average price)	X (natural logarithm of the monthly income of the household)	X	-	number of people in the household whose age is over 65; dummy for the types of dwelling units; dummy for the household's judging whether or not the tap water is suitable for drinking, dummy for the household's currently using the tap water for drinking; dummy variable for city specific effect; Monthly bottled water expenditure of the household; Frequency of the household's visiting spring for getting potable water; dummy for the household's house being equipped with water-conserving tools.
Arbués and Villanua	2006	Daily water consumption in each billing period (converted from a nearly quarterly billing period; from 63 to 114 days between readings)	AP lagged 2 periods (2 quarters) (2 specifications: including or excluding the fixed charge) (the inclusion of the fixed charge is chosen as best based on the Schwarz BIC criterion of model selection)	Proxy variable for income: average earnings in the Autonomous Community of Aragon of a worker with the age and educational level of the head of the household.	X	Dummy variable for average daily maximum temperature (1 if > 18.ºC)	Availability of a commom hot water facility in the building
Fullerton et al.	2006	Water consumption per user	AP	Maquiladora employment; industrial production	-	Precipitation, average temperature	-
Garcia-Valiñas	2006	Quarterly household/firm water consumption	AP lagged two quarters for households and one quarter for businesses (alone and interacted with dummies for the block of consumtpion or the type of meter)	Property value based on street location (proxy for household income); dummies for the type of business as proxy fot the level of economic activity (commercial/ industrial)	X	-	Lagged water consumption (1 quarter for households, 4 quarters for firms); number of hours of supply per period; dummy variable for the deterioration of water pressure or quality; yearly dummies
Gaudin	2006	Per capita annual water consumption	AP; AP interacted with several dummy variables (if MP is indicated next to the units consumed; if MP is indicated next to the units consumed or if the full price schedule is shown; when the bills include consumption history or daily average use; if sewer, electricity and/or gas charges were included in the same bill; if the frequency of billing is monthly; if there was an IBT).	X	X	Average annual precipitation (30-year average); number of days when temperature exceeded 90 ºF (32,(2) ºC)	Population density; Dummy variable for the inclusion of water conservation messages in the water bills

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Hoffmann et al.	2006	Average quarterly household water consumption (regressions performed for three separate groups: all households, owner-occupied households and rental households)	MP	X	X	Number of rainy (>0 mm) and warm days ("daily maximum in the uppermost quartile of all daily temperatures"; "effective cut-off is temperatures greater than 28.5°C")	Dummy for summer quarter; Lagged demand (previous quarter)
Jansen and Schulz	2006	Monthly household water consumption	MP and difference (Taylor-Nordin specification) (instrumentes from a linear approximation to the total water bill and other exogenous variables)	Dummies for income categories	X	Maximum temperature and precipitation	Dummies for the existence of bath/shower, garden, washing machine, year restriction dummies; average age of the household; interaction between marginal price and income categories dummies
Kostas and Chrysostomos	2006	Annual residential water demand	X	Real per capita GDP	-	-	Trend; dummy variables for 1992 and 1994
Larson et al.	2006	Monthly household water use	-	Dummies for income categories	X	-	Dummy for water source (private connection or otherwise); Dummies for head of household's education level; roundtrip walking time to water source; average waiting time at water source; dummy for households that improve water quality before consuming
Mazzanti and Montini	2006	Per capita water consumption	Price of the medium block	Income per capita	X	-	% of population <= 19 years; % of population >= 65 years; population density; number of water users; % of municipal rural area; elderly ratio; altitude
Carter and Milon	2005	Monthly household water consumption	MP and AP	X	X	Precipitation and mean temperature	Lagged consumption; Knowledge on the price of 1000 gallons of water; dummy for own residence; house age; lawn size; dummy variables for dishwasher; irrigation well, only for probit decision model: location dummies, dummy for bottled water drinking, knowledge about low-flow fixtures and xeriscaping
Dalmas and Reynaud	2005	Water consumption per year per capita	X (includes sewerage charge)	Employee wages as a proxy for real income	X	Precipitation (average monthly precipitation from April to September) and Temperature (average monthly temperature from March to September)	Unemployment rate; average number of rooms per dwelling; % of dwellings equipped with an automatic washing machine; average number of square meters of living floor space; % of dwellings used for recreation
Garcia-Valiñas	2005	Quarterly household/firm water consumption	AP lagged 1 period (instrumented from the fixed charge, the difference between MP and the lowest block price and rainfall)	Property value based on street location (proxy for household income); dummies for the type of business as proxy fot the level of economic activity (commercial/ industrial)	X	Precipitation (used in the instrumentation of AP)	Number of supplied hours in the period; dummy variables for the cases where water pressure or quality was below normal levels in the current or previous period; dummy variables for the existence of collective metering (residential); number of unemployed people in the sector (commercial / industrial)
Garcia-Valiñas	2005	Quarterly household/firm water consumption	AP lagged 2 periods for households and 1 period for firms	Real estate value of the house as proxy for income	X	Average maximum daily temperature and total precipitation	Lagged water consumption (1 quarter for households, 4 quarters for firms); Firms: dummies for type of economic activity, street location dummies and annual dummies; Households: dummies for consumptions in the first and second blocks

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
García-Valiñas	2005	Bimonthly household/firm water consumption	AP lagged 2 periods for households; lagged 1 period for commercial/industrial customers	Real estate value of the house as proxy for income. For firms, type of business dummies and location were used as proxies for the level of activity	X	Average maximum daily temperature and total precipitation	Lagged consumption (lagged one period for households; lagged one year for commercial/industrial customers); dummy for houses with collective metering. For firms year dummies were used.
Gaudin	2005	Per capita water consumption	AP; AP interacted with several dummy variables (if unit price information apperas on the bill; when the bills include consumption history or daily average use; if other relevant quantity information is shown; if sewer, electricity and/or gas charges were included in the same bill; if there was an IBT).	X	X	Average annual precipitation (30-year average); number of hot days (when temperature exceeded 90°F (32.2°C) during the survey year)	Population density; Dummy for water conservation messages in the water bill
Hanemann and Nauges	2005	Average daily water consumption	X	Median income, median value of the house	-	Average maximum temperature and total precipitation	Dummy variables for the periods where a voluntary and a mandatory conservation programmes took place; lot size category; % of households with specific education levels, house vintage, % of housing units with more than 7 rooms, and number of owned versus rented housing units; % housing units built between 1960 and 1980; % housing units built between 1980 and 1990
Martins and Fortunato	2005	Monthly average household water consumption	MP (instrumented by the 3 first block prices, remaining exogenous variables, number of meters and % of water losses) and difference	X	X	Temperature, precipitation	Populational density
Reynaud and Thomas	2005	Annual average household water consumption (two separate equations for direct and delegated management)	AP for a monthly consumption od 100 m3 (including sewerage)	Municipal income taxes per household	-	Precipitation in the summer months (June, July and August)	% of new dwellings; % of population >75 years; population density; % of workforce working at home (to account for water consumption of craftsmen and liberal workers); % of principal dwellings; % of households in collective buildings, existence of municipal associations and network efficiency; (also for the selection model); For the selection model of water utility type: real estate value of the houses, according to location; % of old dwellings; area of the municipality; location dummies; customers/population; existence of autonomous sewerage; aquisition of all raw water from a bulk provider; average water bill; proportion of industrial consumption; number of water boreholes; ratio of peak consumption to mean consumption; average household water consumption; network length per customer;

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Reynaud et al.	2005	Monthly water consumption of the representative household (separate regressions for different pricing structures); Regression model for the choice of the pricing structure	MP (including sewage charges) (instrumented from the "marginal price for 10, 25 and 35 m3/month, the upper bound of the first block, the lower bound of the last block, the number of blocks and some socioeconomic variables describing the average household" when IBR or DBR are implemented); AP used for the flat fee cases	X	-	-	Inverse of Mill's ratio from the pricing structure choice model; Regressors used for the water demand model and for the pricing structure choice regression: average biochemical oxygen demand (BOD) of influents and effluents, the share of groundwater in total water supply, the share of the population without any sewage plant; dummies for the existence of treatment or disinfection prior to water use; unemployment rate, the share of the population without any earned income and the ratio of the domestic water consumption to the total water consumption; ratio of the difference between median and average incomes to the average income, standard error of the average income; share of rural population; categorical variable representing the size of the municipality; average number of room per dwelling; share of dwellings built before 1946 (or after 1991); share of individual houses; number of days with restriction in use (or in boil) in 1993, 1995 and 1998; number of years with water quantity (or quality) problems; population density; population change between 1991 and 1996; pro
Strand and Walker	2005	Monthly household water consumption	MP and Difference (Taylor-Nordin specification) AP (all instrumented); water price and hauling costs for nontap water	Income and value of the house	Number of adults and number of children (tap water); household size (nontap water)	-	Existence of telephone; City dummies; dummies for the number of daily service hours
Arbués et al.	2004	Daily household water consumption	AP (lagged 2 periods, with and without the fixed charge); Daily expenses (also lagged 2 periods); MP	Property value (proxy for income)	X	-	Availability of common hot water facility (with a separate common meter)
Fullerton and Elías	2004	Monthly consumption per connection	AP	Non-agricultural employment used as a proxy for economic conditions	-	Precipitation, number of days with preciptation and the number of days with temperatures above 90° Fahrenheit	-
Garcia and Reynaud	2004	Water consumption per customer	MP	X	X	Summer precipitation	% of housing not equipped with a bath or toilet, % of housing with less than 8 years old; average number of employees per industrial firm; proportion of firms operating in the electricity, gas, water and construction sector; proportion of industrial users

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Martínez-Espiñeira and Nauges	2004	Water consumption per capita	MP (includes wastewater charges) ("instrumental marginal price derived from a linear regression of the theoretical water bills associated with all integer values of monthly water use per account between 1 m3 and 25 m3", the slope of the estimated function)	Virtual income (average salaries - difference (Taylor-Nordin specification)) ("instrumental difference derived from a linear regression of the theoretical water bills associated with all integer values of monthly water use per account between 1 m3 and 25 m3", the intercept of the estimated function)	-	Precipitation in month t (historical averages for the period 1961–1990)	Number of daily hours of water supply restrictions during drought periods (weighted by the number of hours in the month); dummy variable with value 1 when temporary outdoor-use bans were applied during the drought; Population; Lagged average past consumption used in the model with varying threshold
Mylopoulos et al.	2004	Household water consumption (1 observation = 2 months)	MP and AP (separate regressions for each - marginal price specification is found to be superior)	Proxy variable for income derived from the regression of income on type of dwelling; coded floor of the building; residence surface area; dummy for property ownership; dummy for swimming pool ownership; dummy for WTP for improved service; dummies for wether the head of the household finds the water rates low-priced, reasonable or expensive; dummy for municipality	Number of household residents	Precipitation (four months sum); Temperature (four months average temperature)	Dummy variable for employees of the water authority; Temporal dummy variables to account for three periods with different tariffs; dummies for families with more than 4 children; type pf dwelling dummy (1 for apartment); dummy for car washing; dummy for watering plants; dummy for cleaning balconies; dummy for cleaning pavements;
Taylor et al.	2004	Monthly per capita water consumption	MP and AP (estimated simultaneously from consumption per capita, number of connections, customer density (customer/population), dummy variables for tariff types, and blocks	X	-	Monthly precipitation and highest annual temperature	Dummy for water conservation programs; dummy for summer months (June, July, August and September); dummies for tariff types (uniform pricing, IBT, DBT and fixed monthly charge)
Ayadi et al.	2003	Quarterly average household water consumption (one regression for each block of consumption (with one observation in each region and period for each block); and an additional regression of the proportion of users in each block on all explanatopry variables except income)	AP, AP instrumented by MP, AP calculated based on share of consumers in each block	Average household income	-	precipitation	Size of the distribution network; quarterly dummies; regional dummies for the model combining all observations
Dalhuisen et al.	2003	Price-elasticity of water demand; Income-elasticity of water demand	MP vs AP vs Shin price or price perception; Inclusion of difference variable; Types of tariff structures	Income included; GDP per capita of the region	X	Evapotranspiration, precipitation and temperature	Long-run vs. Short-run; West USA vs. East USA vs. Europe vs. other; functional form; population density; seasonal dummies; lagged dependent variable; commercial use included; estimation techniques (OLS vs. DCC model vs. Other); data frequency; type of data (household vs. Aggregate; cross-section vs. panel data vs. other; winter vs. summer vs. annual); unpublished studies; time trend
Fullerton and Nava	2003	Total municipal water consumption	AP	Industrial Production	-	Average precipitation and Temperature	-

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Garcia and Thomas	2003	Per capita water demand	AP (including wastewater charges)	-	-	-	-
Krause et al.	2003	Water consumption (amount of water withdrawn from a given stock) in a controlled experiment	AP	X	-	-	Age, education, dummy variable for whether the person had been in a experiment group which fully depleted its stock, gender, ethnicity, political affiliation, religious affiliation, risk preferences; dummies to distinguish workforce participants and retirees from students
Martínez-Espiñeira	2003	1st stage: proportion of users per block; 2nd stage: average water use per account per month	2nd stage: MP and difference (Taylor-Nordin specification), average/weighted MP and average/weighted difference (the weights are proportion of users per block)	1st and 2nd stages: Estimated family disposable income per capita (data in intervals)	-	1st and 2nd stages: Average temperature in each month	1st stage: % of population under the age of 19; % of population over 64 years of age; 2nd stage: % of population over 64 years of age
Nauges and Thomas	2003	Annual household water consumption	MP	X	-	-	Lagged consumption
Piper	2003	Average monthly household water consumption	AP	X	X	Temperature, precipitation	Water quality of water delivered measured in terms of annual average total hardness (mg of total calcium cabonate per liter of water) measured as a five-categories ordinal variable
Acharya and Barbier	2002	Water collected and Water purchased from water vendors	X	-	X	-	Children/adult ratio; occupation; dummies for water sources; water collection time; several interaction terms
Agthe and Billings	2002	Water use/apartment/month	MP	-	Number of bedrooms per apartment as a proxy for household size	-	Value per bedroom, apartment age, indoor water-saving devices; swwiming pools; vacancy rates (% of unoccupied apartments); dummy for drip with timer irrigation for nongrass landscaping
Hajispyrou et al.	2002	Share of water in household expenditure on nondurable goods	MP	household income	Number of adults	-	Dummies for: type of dwelling; type of ownership; year of completion of residence; kitchen, shower and toilet characteristics; running water; childrens' age; characteristics of the head of household's job and education; ownership of several water-using appliances. Age of the head of household. Dwelling area. Expenditures on: waste disposal and sanitary services; dwelling rent and insurance; water pump; domestic servant; gardener. Regional dummies.
Ipe and Bhagwat	2002	Per capita water consumption	AP, MP	Annual per capita income	-	weather variable (sum of the number of days with precipitation less than 0.1 inch during the months from April to October multiplied by the average monthly temperature for that month)	-

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Martínez-Espiñeira	2002	Average monthly water use; Average monthly water use in excess of the free allowance; Average monthly water use in the summer	MP and difference (Taylor-Nordin specification) (instrumentes from a linear approximation to the total water bill) (includes sewage charges); AP for monthly use of 10m3, MP for monthly use of 10m3 and the difference between both	Per capita household disposable income	X	Number of rainy days; Average temperature	Size of the free allowance (after paying the fixed charge); % of population over 64; % of dwellings occupied as main residence; frequency of billing (number of billing periods in a year)
Nauges and Blundell	2002	Annual water consumption per household	block prices and block limits (nonparametric estimation); MP (for the remaining techniques; instrumented in 2 SLS and ML, like difference, from the block prices, the fixed charge, the income, house size, household size and the dummy for washing-machine ownership); squared prices and incomes and the interaction between income and price are used for an alternative ML model.	Virtual income (calculated from gross household income and the difference variable)	X	-	Residence size; dummy for washing-machine ownership
Pashardes and Hajispyrou	2002	Share of water in household expenditure on nondurable goods	MP (instrumented from the remaining exogenous variables)	X	Number of adults; number of children	-	Washing machine; dishwasher; area of the dwelling; shower and toilette (inside or outside); running water; head of household in agriculture; head of household retired; sewage system; regional dummies
Gaudin et al.	2001	Daily per capita water consumption	AP (including sewaerage charges)	Per capita income	-	Days with precipitation < 0.25 inches * average temperature; 60 year average annual precipitation	% of population of Spanish origin; dummy variables for month and year
Gunatilake et al.	2001	Monthly household water consumption	MP and Difference (Taylor-Nordin specification)	X	X	-	-
Higgs and Worthington	2001	Daily household water consumption	MP (instrumented from a the rate schedule values and the consumption quantities estimated from a regressioin of quantity on all explanatory variables except MP)	Income; Ratable value of the property	X	-	Seasonal dummy for summer; Dummy for year; 10 principal components from: pensioner status; number of times the lawn is watered per week; type of garden vegetation (native vegetation, vegetable crops); property and yard size; water absorbency of soil; number of car washes per week; dummy variables for below-ground and above-ground pools; spas; wading pools; number of showers, baths, hand basins, laundries, washing machines and sinks; dummy variables for dual-flush toilets, dishwashers and garbage-disposal units
Nauges and Reynaud	2001	Average annual water consumption per household (separate regressions for Gironde and Moselle)	AP for an annual consumption of 100 m3 (Gironde), MP (Moselle) (prices include sewage charges)	Net income; taxable income	% of households with 1 or 2 persons	Total precipitation in June, July and August; Total annual precipitation	Population density (hab/km2); % of population aged over 60 years; % of population aged less than 20 years; % of households owning at least one car; % of single housing units; % of houses with bathtubs; % of houses built before 1949; % of houses built after 1982; Variables used to test the price endogeneity: For Gironde: Number of connections/subscribers; length of the distribution network; distribution network efficiency (distributed volume/consumed volume); net loan annuities of the water utility per subscriber; ratio of industrial water use to residential water use; For Moselle: number of connections; network lenght; number of repaired leaks

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Nauges and Thomas	2000	Average annual water consumption per household	MP and AP (AP chosen after passing exogeneity test)	Average income before tax; industry activity rate of growth	% of households with 1 or 2 persons	Average annual precipitation; total summer precipitation	% of metered households; Number of connections to the system; number of detected leaks; length of the distribution network; % of the population aged over 60 years; Population density; % of single housing units; % of houses with bathtub; % of households owning at least 1 car; % of houses built before 1949; % of houses built after 1982
Renwick and Green	2000	Average monthly household water consumption	MP and difference (Taylor-Nordin specification) (instrumented from lagged marginal price for each block of the rate schedule and the remaining socioeconomic exogenous variables); Dummy for block pricing	Average monthly gross household income	-	De-seasonalized average maximum daily temperature and precipitation (deviations from estimated historical hamonic means: Fourier series of sine and cosine terms of various harmonic frequencies)	Dummies for public information campaigns; and subsidies to encourage adoption of more water efficient technologies (ultra low flow toilet rebate programs and distribution of free retrofit kits); rationing programs; water use restrictions; compliance affidavit saying that water efficient devices were installed. Dummies for low or significant irrigation (expected differences in outdoor water use patterns by the agency); Lot size
Rietveld et al.	2000	Monthly water consumption	MP	Virtual Income (income of a household conditioned on the marginal price it pays for water)	X	-	Dummy variable for the case where a household has an extra water source (usually the river or a well)
Corral et al.	1999	Average monthly water consumption	MP and difference (Taylor-Nordin specification), average/weighted MP and average/weighted difference (the weights are proportion of users per block)	Virtual income (income + difference)	-	Temperature and precipitation	15 dummy variables for conservation and education programmes, billing information, water use restrictions
Dzisiak	1999	Average quarterly household water consumption	MP, AP	X	-	Net available moisture (precipitation - potential evapotranspiration from grass)	Average number of rooms per house; Dummies to diferentiate the quarterly billing periods; dummy variables for monthly and bimonthly billing periods. Dummy variable for drought periods (also interacted with price)
Höglund	1999	Quantity of metered water per house	MP and AP	X	X	-	Regional dummy
Merrified and Collinge	1999	Household water consumption	-	Per capita income	-	-	Population
Pint	1999	Household water consumption	MP and MP^2	-	-	Precipitation, temperature, lagged precipitation and lagged temperature	House size and lot size
Renzetti	1999	Total water consumption by households; Total water consumption by nonresidential customers; total wastewater drained	MP of water and price of sewage treatment for a cunsumption of 20m3/month for residential customers and 100m3/month for nonresidential customers	X (for the household equation)	-	5 variables: Number of days per year when temperature >25.ºC and >30.ºC; when precipitation is between 2 and 10mm, between 10 and 25 mm and >25mm	Price of electricity; number of households (for the household equation); value of the manufacturing sector's output and number of manufacturing firms (for the non-household equation)

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Billings and Agthe	1998	Average monthly household water consumption	MP and difference (Taylor-Nordin specification) (instrumentes from a linear approximation to the total water bill)	Real income per capita	-	Average temperature and total precipitation (in deviations from the historic average)	Monthly dummies
David and Inocencio	1998	Monthly household water consumption	MP and difference (Taylor-Nordin specification)	Household income	X	-	Distance from water source; dummy variable for water source, for water quality perception variable, for home ownership and sewer connection; number of years of schooling; number of supply hours
Largo et al.	1998	Monthly household water consumption	MP	Household income	X	-	Dummy variable for quality perception variables, home ownership and use of shower; Type of sanitation system (ordered in relation to the water use)
Mattos	1998	Monthly average household water consumption	MP and difference (Taylor-Nordin specification)	Added value in the municipality (as a proxy for income)	X	Temperature and precipitation	-
Renwick and Archibald	1998	Monthly water consumption	MP and difference (Taylor-Nordin specification)	Gross monthly household income	X	Precipitation	Variable for the adoption of domestic and landscape irrigation technologies (low flow toilets, low flow showerheads; water efficient irrigation (drip and hand held) and traditional irrigation (sprinklers and hoses)) (previously estimated from technology adoption equations); Number of taps; dummy variables for lot size (to identify outdoor water consumption); dummies for specific restriction policies; regional and monthly dummy variables; home ownership (only for the technology adoption equations)
Agthe and Billings	1997	Monthly water purchased	MP and difference (Taylor-Nordin specification) (instrumented from a regression of the water bill on quantities consumed)	Average per capita income	-	Temperature and precipitation	-
Dandy et al.	1997	Annual water consumption	MP and difference (Taylor-Nordin specification)	Property value (proxy for income)	X	Summer moisture deficit (potential evapotranspiration - 0.6 precipitation)	Plot size; Number of rooms; Pool ownership; Seasonal dummy variable; Water consumption lagged one year (regressions performed with and without this variable creating static and dynamic models); Dummy variable = 1 if consumption is above the free allowance (and interaction between this dummy and all other variables, separately)
Espey et al.	1997	Price-elasticity of water demand	MP, AP, MP and difference and Shin price or price perception	X	X	Evapotranspiration, precipitation and temperature	Population density, seasonal dummy, long-run demand, lagged dependent variable, functional form (linear and log-linear) and estimation technique (OLS and other than OLS)
Malla and Gopalakrishnan	1997	Total monthly water use by multi-unit dwellings; water per unit; water per capita	MP and difference (Taylor-Nordin specification)	X	Number of residents	precipitation	Number of dwelling units in the multi-unit; Number of swimming pools

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Saleth and Dinar	1997	Average monthly water consumption (for all cases, or divided by consumption barcket or divided by housing category (bungalow with and without garde, traditional house, house in the slum areas)	MP and difference (Taylor-Nordin specification) and AP	-	X	-	-
Barkatullah	1996	Quarterly household water consumption	MP and difference (Taylor-Nordin specification) (regression of observed demand on the fixed charge, 3 block prices and the remaining exogenous variables, after which predicted consumption values are used to calculate instrumented marginal prices and difference values for the main regression)	Household income and assessed value of the house	X	Temperature and lagged precipitation	Dummy variable for summer quarters; number of bedrooms; number of bathrooms/toilets; garden condition
Dziegielewski	1996	Price-elasticity of demand	MP	-	-	-	Dummies for significant estimate, IBT, log-linear equation and Eastern US; short-run elasticity, average annual demand, summer season demand, sprinkling demand
Hansen	1996	Per capita water consumption	MP (current and lagged) (divided by the number of apartments sharing a common meter if that is the case)	Disposable gross income	-	Sprinkling need index based on summer precipitation (one for each type of house: detached, row, apartment)	Energy price (current and lagged); dummy variables for detached and row houses
Andrade et al.	1995	Monthly household water consumption	MP and difference (Taylor-Nordin specification) (regression of observed demand on marginal prices for specific valus of consumption, after which predicted consumption values are used to calculate marginal prices from the rate schedule (IV))	Household income categories and also separate regressions for different household income categories	X	-	-
Hewitt and Hanemann	1995	Monthly household water consumption	MP and difference (Taylor-Nordin specification) (includes sewerage charges) (two types of instrumentation for the 2SLS and the IV models: regression of price on exogenous variables and marginal prices for specific values of consumption (2SLS); regression of observed demand on marginal prices for specific valus of consumption, after which predicted consumption values are used to calculate marginal prices from the rate schedule (IV))	Monthly income proxy calculated from the assessed value of the house	-	Potential evapotranspiration for bermuda grass minus precipitation	Number od days in the billing period; Lawn size; Number of bathrooms

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Bachrach and Vaughan	1994	Household water consumption	MP and Difference (Taylor-Nordin specification) (instrumented from rate charged per cubic meter of water in 14 consumption block intervals and location dummies)	Income and the electricity bill as a wealth proxy	Number of adults in the household	-	Number of water faucets; Average number of service interruptions per month
Crane	1994	Monthly household water consumption (2 separate regressions: from water vendors and from public taps)	Unit price	Monthly household income	X	-	dummy for water source; time necessary to puchase or to collect water; distance to nearest hydrant; time to commute to work; age of head of household; years in house; tenant; house size; dummy for shared toilet; reservoir capacity; rural location dummy
Walters and Young	1994	Average monthly household water consumption	AP, MP and MP and Difference (Taylor-Nordin specification)	X	X	Average maximum summer (June, July and August) temperature and average monthly summer precipitation	Frequency of billing; Conservation education programs
Boistard	1993	Average per capita water consumption	AP for a consumption of 100m3 per year (with and without sewer charge)	-	-	-	-
Nieswiadomy and Cobb	1993	Monthly household water consumption; type of block structure (uniform, DBT or IBT) in selection model	MP, AP and price perceived (MP(AP/MP)^k) (for 1000 gallons)	Per capita monthly income	X	Temperature and precipitation for months between last spring freeze and first fall freeze	Dummy variables for public education programme, for conservation programme and for location in California; % of homes built before 1939; % of homes that are owner occupied. Additional variables for the selection mode: percustomer debt of utility; % of residential customers; % of water purchased by the utility; population served; average and maximum day usage as a % of system capacity, 1951-1980 average annual rainfall and July temperature; annual population growth rate 1970-80; total population growth rate 1980-86; average home value
Point	1993	Average consumption per capita	AP for a consumption of 150m3 per year	Fiscal potential	-	-	Square root of the ratio between nonpermant and permant habitants; área por habitante
Lyman	1992	Bimonthly household water consumption	MP, ratio of peak to off-peak MP, fixed charge (all lagged one period)	household income and assessed value of house and property	-	Temperature and precipitation (linearly and squared); number of cooling degree days and of heating degree days	Average age of household members; number of persons <10 years, between 10 and 20years, and older than 20 years of age; age of the house; number of bathrooms; dummy variables for water heat, sprinkler system, peak and off-peak period, spring and peak and srping together; price index; Past water consumption; indexes for lawn size, degree of yard shaded; size of flower garden, size of vegetable garden
Martin and Wilder	1992	Monthly household water consumption	MP and AP (instrumented from MP, income and the set of monhly dummy and interacted variables)	Household income (proxy for water using appliances ans the intensity of thier use)	-	-	Monthly dummy variables (alone and interacted with income)
Nieswiadomy	1992	Monthly household water consumption	MP, AP and price perceived	Per capita monthly income	X	Temperature and precipitation	Dummy variables for the existence of a water conservation program and for na educational program; % of homes built before 1939; % of homes that are owner occupied

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Renzetti	1992	Household water consumption; industrial water consumption	other (instrumental variable for price)	Household available income	X	Temperature and precipitation	Added-value by manufactures in the region and % of self-supplied water (for the industrial demand regression)
Stevens et al.	1992	Average household water consumption	AP (including sewer charges) (instrumented from the minimum service charge and the remaining exogenous variables)	Per capita income (proxy for water using appliances)	-	Temperature and precipitation	Billing frequency; population density (proxy for urban/rural differences such as lawns and gardens); dummy variable for location; dummy variables for type of rate structured (also interacted with the remaining exogenous variables - 3 different regressions in practice)
Woo	1992	Per capita water consumption	AP; Instruments used for Hausman test: exogenous variables, first and last residential block rate, average of block rates, difference variable at the last block, number of blocks, commercial rate	Per capita income	-	Precipitation-evaporation; temperature	Monthly hours of supply; monthly dummy variables
Griffin and Chang	1991	Per capita residential and commercial water consumption	AP	Per capita income	-	Number of days without significant precipitation (≥ 0.25 inches); Average annual precipitation	% of population from hispanic origin
Nieswiadomy and Molina	1991	Monthly household water consumption	AP/MP and MP to test the k paramenter in price perceived (MP(AP/MP)^k). [AP is from the previous month] (AP includes all charges for water and sewage) (MP instrumented from lawn size, weather, income house size, flat fee and 3 block prices during DBT and 2 block prices during IBT)	Income proxy based on the value of the house	-	Weather variable (Potential evapotranspiration for Bermuda grass - Precipitation); Water consumption lagged one month	Lawn size
Rizaiza	1991	Annual household water usage	AP	Average annual family income	X	Temperature	Number of school years of the head of household; dummy variables for houses with gardens and for houses with sewers (instead of septic tanks); dummy variables for water supply by tanker (instead of public water network); city dummy variables
Schneider and Whitlatch	1991	Average annual consumption per account	MP (including sewer rates)	Per capita income	X	Summer precipitation (May-August)	Housing composition (single-unit dwellings/total dwellings)

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Billings	1990	Monthly household water consumption	AP	Monthly household income	X	Average temperature, high temperature (degrees exceeding 58ºF), monthly summer precipitation, % of annual daylight hours during month	Lagged water consumption, ratio of current customer to customers in January 1974; % of heads of household aged between 55 and 64 and aged 65 and over
Griffin and Chang	1990	Per capita and per day residential and commercial water consumption	AP (including sewer charges) paid by na average 2.84 person household and MP-AP; rate change dummy variable (=1 if rate changed in the current or in the previous 2 months) (AP is preferred)	Annual personal income per capita	-	Number of days without significant precipitation (≥ 0.25 inches) * month's average temperature	% of population with spanish origin
Miaou	1990	Annual per capita water produced	AP	Per capita income	Number of households per unit of population	Precipitation and temperature (year and summer averages)	-
Mu et al.	1990	Water used per capita per day ("water carried home") [a discrete choice model for the water source is also estimated]	-	X	-	-	Time it takes to collect water from different sources; Proportion of women in a household; perception of the taste of water; numer of years of formal education of household members; dummy variable for the type of water access (water kyosk; water vendor; wells)
Billings and Day	1989	Monthly household water consumption	MP and difference (Taylor-Nordin specification) and AP	X	X	Temperature, precipitation	Weighted index of articles appearing in the leading area newspaper related to water problems; % of homes occupied by owner; % of people aged 55-64; % of people aged 65 or older; % of new households; growth in water connections
Moncur	1989	Average daily water pumpage	X	X	-	Rainfall, lagged rainfall	Dummy for water restrictions
Nieswiadomy and Molina	1989	Monthly household water consumption	MP and difference (Taylor-Nordin specification) (includes sewerage charges); MP and AP (MP and difference instrumented from lawn size, weather, income house size, flat fee and 3 block prices during DBT and 2 block prices during IBT; alternatively (IV model); MP and difference are calculated from a regression of water demanded on actual marginal prices for different levels of consumption (2SLS model))	Monthly income proxy calculated from the assessed value of the house	-	Potential evapotranspiration for bermuda grass minus precipitation	Lawn size; house size

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Weber	1989	Monthly household water consumption	MP	Monthly household income	-	Average monthly precipitation and mean maximum temperature; actual precipitation and temperature; deviation of precipitation and temperature from historical values; moving averages of precipitation and temperature	Seasonal index, monthly dummy variables, time trend
Wilson	1989	Average summer sprinkling water use	MP	Market value of the dwelling unit (proxy for income)	-	Moisture deficit (summer [June August] evapotranspiration minus effective [0.6] precipitation)	-
Nieswiadomy and Molina	1988	Monthly household water consumption	MP and difference (Taylor-Nordin specification) (includes sewerage charges) (two types of instrumentation: regression of price on exogenous variables and marginal prices for specific values of consumption (2SLS); regression of observed demand on marginal prices for specific valus of consumption, after which predicted consumption values are used to calculate marginal prices from the rate schedule (IV))	Monthly income proxy calculated from the assessed value of the house	-	Potential evapotranspiration for bermuda grass minus precipitation	House age; lawn size
Palencia	1988	Average monthly household water consumption	MP and difference (Taylor-Nordin specification)	Average household income	X	-	Total population (index for urbanization)
Thomas and Syme	1988	Average annual household water consumption (with and without adjustment to account for boreholes)	MP and difference (Taylor-Nordin specification)	X	X	Precipitation	Hours per year of restrictions on water supply; % of households with private groundwater borehole or well
Agthe and Billings	1987	Monthly household water consumption (for 4 different income groups)	MP and difference (Taylor-Nordin specification); dummy variables for simultaneous change in MP and difference and for changes only in difference.	Personal income per household	X	Evapotranspiration minus precipitation	Dummy for swimming pools, frontyard and backyard vegetation
Billings	1987	Monthly household water consumption	MP and difference (Taylor-Nordin specification) (instrumentes from a linear approximation to the total water bill)	Monthly household income	X	Average temperature, high temperature (degrees exceeding 58ºF), monthly summer precipitation (for the months when temperature exceeds 58ºF)	Estimate of water-related publicity; % of homeowners, % of heads of household aged between 55 and 64 and aged 65 and over; new households (% of households in home 1 year or less); ratio of current customer to customers in January 1974
Frerichs et al.	1987	Annual water demand per connection	AP and MP and Difference (Taylor-Nordin specification)	X	X	-	Dummy variable for large cities; % of people <18 years of age

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Moncur	1987	Household water consumption	MP	Income per household member	X	precipitation	Dummy (water restrictions program)
Schefter	1987	Average quantity of water demanded per household per year	MP and difference (Taylor-Nordin specification)	X	-	-	-
Agthe et al.	1986	Monthly household water consumption	MP and difference (Taylor-Nordin specification) instrumented from water consumption, dummy variables for price changes in water and sewer tariffs	Personal household income	-	Evapotranspiration minus precipitation	Past water consumption; time trend
Chicoine and Ramamurthy	1986	Monthly household water consumption	MP, AP-MP (decomposed price variable)	Virtual income (income - difference variable)	X	-	Monthly dummy variables; Number of bathrooms
Chicoine et al.	1986	Household water consumption	MP and difference (Taylor-Nordin specification), AP (all instrumented from water consumption, minimum bill, average marginal price in the rate structure and average changge in marginal price from moving from one block to the next) and others	Household income	X	-	Number of bathrooms
Deller et al.	1986	Monthly household water consumption	MP and difference (Taylor-Nordin specification)	Monthly household income	X	-	Number of bathrooms
Martin and Thomas	1986	Average daily per capita water consumption	MP	-	-	-	-
Williams and Suh	1986	Annual water demanded by customer class	MP, AP and other (typical monthly bill for consumptions of 3750, 7500 and 7500 gallons)	X (only for residential equation)	-	Summer temperature (for residential and commercial equations) and summer precipitation (only for residential equation)	Added values in manufacturing (only for industrial equation); receipts in establishments of selected services (only for commercial equation); Number of customers in each class; population density (only for residential equation)
Al-Qunaibet and Johnston	1985	Per capita monthly water consumption	AP	Per capita income	-	Relative humidity (estimated from mean temperature, mean minutes of sunshine, mean wind speed)	-
Cochran and Cotton	1985	Annual water production per capita	AP	Per capita income	Number of households per unit of population	Precipitation and temperature	-

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Schefter and David	1985	Household water consumption	MP and difference (Taylor-Nordin specification), average/weighted MP and average/weighted difference (the weights are proportion of users per block)	Average household income	-	-	-
Jones and Morris	1984	Water use of single-family residences	MP and difference (Taylor-Nordin specification) (instrumental variables developed from average water use b rate class during summer and winter) and AP (instrumental variable: AP was estimated from a regression of the logarithm of observed average price on exact rate information such as the fixed component, initial variable charge and the difference in charges between subsequent and adjacent blocks)	Family income (instrumental variable regressed from property value of the residence; construction date of the residence; educational level of the head of the household; job of the head of the household; numer of cars registered at the address)	X	-	-
Young et al.	1983	Quarterly household water consumption by low, medium and high consumption groups	-	Assessed value of the house (proxy for income)	X	-	Annual time trend; seasonal dummies; dummy for the use of water conservation devices; dummy for the use of dishwashing machines
Billings	1982	Monthly water consumption of the average household	MP and difference (Taylor-Nordin specification) (instrumentes from a linear approximation to the total water bill)	X	-	Evapotranspiration minus precipitation	Implicit sewer charge during winter months
Hanke and de Maré	1982	Water consumption per house	MP	X	X (2 separate variables: number of adults per house and number of children per house)	precipitation	Dummy variable for the age of the house (1 for houses built in the period 1968-69, o otherwise, i.e., built in the period 1936-1946)
Howe	1982	Daily household water consumption	MP and difference (Taylor-Nordin specification)	Market value of the dwelling unit (proxy for income)	-	Moisture deficit (calculated from outdoor irrigable area, potential evapotranspiration rate and averge summer precipitation rate)	-
Ford and Ziegler	1981	Household water consumption	MP and AP	Household income, house value and financial resources	X	Temperature and precipitation	Household average age, number of children; number of water using appliances; of plumbing fixtures; of faucets; size of swimming pool; lawn area; garden area; perceived water quality; town size; age of water using appliances
Foster and Beattie	1981	Average quantity of water demanded per household	MP and difference (Taylor-Nordin specification) compared to the AP specification of Foster and Beattie, 1979.	Median household income	Average number of persons per service meter (may include more than one household)	Precipitation during the growing season (months where the temperature is at least 45ºF in the North and 60ºF in the South)	-

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Agthe and Billings	1980	Monthly water consumption	MP and difference	X	-	Evapotranspiration minus precipitation	-
Ben-zvi	1980	Non-industrial use per customer (lowest monthly use for winter demand regression; average use in April-September - average use, for summer water demand)	MP (nonindustrial) plus treatment cost; average cost of sefl-supplied water (industrial)	Value of sales	-	-	-
Billings and Agthe	1980	Average monthly household water consumption	MP and difference (Taylor-Nordin specification)	Real income per capita	-	Evapotranspiration minus precipitation	Implicit sewer charge during winter months
Carver and Boland	1980	Water consumption per connection per day (different models for nonseasonal [November-April] and seasonal consumption [May-October minus the average of November-February])	MP	Real household income	X	Moisture deficit (evapotranspiration minus efective precipitation) (only for seasonal model)	Dummy variable for the imposition of a excess use charge; Past water consumption (lagged 1 year); employee per connection; household-specific and time-specific dummy variables
Cassuto and Ryan	1979	Monthly household water consumption	MP (price of the first block) (current and lagged)	Real mean income per household	X	Temperature (valued 0 if <65ºF [18.3ºC]) and precipitation	Lot size; weekend days per month; weighted average elevation of census tract; energy price index; time trend; days per month; dummy variable for month
Colander and Haltiwanger	1979	Water produced/pumped per active account	AP	-	-	precipitation	-
Danielson	1979	Separate winter/indoor and summer/outdoor water consumption	MP (price of the first block)	Value of the house (proxy for income)	X	Temperature and precipitation	-
Foster and Beattie	1979	Quantity of water demanded per meter	AP	Median household income	Average number of persons per service meter (may include more than one household)	Precipitation during the growing season (months where the temperature is at least 45ºF in the North and 60ºF in the South)	City/region dummy variables (USA divided in 6 regions); Size-of-city dummy variables
Camp	1978	Monthly household water consumption	MP	Market value of the residence (proxy for income)	X	Average maximum temperature and total annual precipitation	Age of head of household; irrigable lawn area of residence; number of bathrooms, clothes washers and dishwashers. Existence of a swimming pool; Race; Educational index
Gibbs	1978	Quarterly household water consumption	MP and AP; dummy variable for zero-price cases	Annual household income	X	-	Seasonal dummy variables; % of homes with hot-water heat

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Katzman	1977	Average monthly household consumption	Dummy for price increase	Income dummies (high income, middle incom, poor)	Number of household members over and under 16 years of age	precipitation	Dummy for urban residence; dummy for alternative sources of water; time trend
Clark	1976	Per capita water consumption	MP	-	-	-	-
Grunewald et al.	1976	Quantity of water used per household	AP	Mean household income	X	Potential evaporation (June-September)	Value of the dwelling unit
Morgan and Smolen	1976	Municipal water use per capita per day (4 different models/samples: total sample or 12 months; wet season (November through March, revealing indoor water use); dry season (April through October); Sprinkling demand (total sample with the minimum consumption form the wet season subtracted to reveal summer sprinkling demand)	AP (time-invariant over the 12 months of the study)	Median family income (time-invariant over the 12 months of the study)	-	3 alternative climatic specifications (temperature and precipitation; potential evapotranspiration - precipitation; monthly binary seasonal variables) (the use of temperature and precipitation yields the best results)	-
Andrews and Gibbs	1975	Household water consumption (different regresssions for MP and AP)	MP and AP (in the MP model a dummy variable is introduced to differentiate zero and non-zero MP)	Annual household income	X	-	% of households with hot heater; seasonal quarterly dummy variables (February-April, May-July, August-October and November-January)
Attanasi et al.	1975	Per capita water consumption	AP	X	-	-	-
Batchelor	1975	Annual household water consumption	-	Net annual value of the property	X	-	Age of the house; dummy variables for the existence of toilets and to distinguish apartments from houses with gardens; number and type of the following water using appliances: washing machines, cars, dish-washers, showers and garden sprinklers
Darr et al.	1975	Per capita water consumption (3 separate regressions: including and excluding gardening and gardening only)	-	Gross monthly household income	X	-	Cultural origin; education and age of the head of household; number of rooms per household; regional dummies
Hogarty and MacKay	1975	Per capita water consumption	MP	-	-	-	-
Morgan	1974	2 regressions: Quantity of water consumed by each household; total water consumed in each billing period	Dummy variable for an increase in price for the last 6 billing periods	-	-	precipitation	Dummy variables for the individual households (not included in the 2nd regression); Seasonal dummy variables for each bimonthly period within a year; Linear time trend increasing one unit each bimonthly period

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Grima	1973	Average daily water use per dwelling (3 separate regressions: year, summer, winter)	Variable price; Fixed bill	Assessed value of the residence	X	-	-
Morgan	1973	Water consumption (for November-December; for January-February; for the 4 months combined)	-	-	X	-	Assessed value of property
Young	1973	Water produced/pumped per active account	AP	-	-	precipitation	-
Wong	1972	Per capita water consumption	AP	Average household income	-	Average summer temperature (only for the time-series regression)	-
Hanke and Davis	1971	Water consumption per user (separate regressions for residential indoor, residential sprinkling, commercial/ industrial, public/ innacounted; separate regressions for winter and summer)	MP (second-block rates)	-	-	-	-
Hanke	1970	Sprinkling water consumption; Indoor water consumption	Dummy variable for the introduction of metering and a single volumetric charge	-	-	"Ideal sprinkling consumption" (based on "average irrigable area per dwelling unit, mean monthly temperature, monthly percent of daylight hours, effective precipitation, and na empirical monthly crop coefficeint for grass"	Interaction between the ideal sprinkling consumption and the dummy variable
Turnovsky	1969	Per capita water consumption	AP	-	-	-	Index of per capita housing space (rooms/occupants) and % population <18 years (both only for residential regression); index of per capita industrial production (only for industrial regression); Variance of water supply
Meroz	1968	Average daily per capita water consumption	AP; dummy for volumetric charge	Per capita income	-	Average daily maximum temperature; precipitation-temperature index	% of population served
Conley	1967	Per capita consumption	MP (per 1000 gallons and per 10000 gallons) and AP (per 1000 gallons)	-	-	-	-
Howe and Linaweaver	1967	Water consumption per dwelling unit (Separate winter/indoor and summer/outdoor/sprinkling)	MP (including sewer charges); Marginal summer charge (for sprinkling regression only)	Market value of the dwelling unit (proxy for income)	X	For sprinkling regression only: summer potential evapotranspiration; Maximum day potential evapotranspiration; summer precipitation	Average water pressure; age of the house; for sprinkling regression: irrigable area per dwelling unit; maximum day sprinkling demand
Bain et al.	1966	Per capita consumption	AP	-	-	-	-
Flack	1965	Per capita consumption	AP	-	-	-	-

Authors	Year of publication	Dependent variable - water consumption / demand	Explanatory variables				
			Price	Income	Household size	Weather	Others
Gardner and Schick	1964	Daily per capita water consumption	AP	Per capita income	-	Temperature and precipitation	Per capita lot area; % of homes with complete plumbing units
Gottlieb	1963	Per capita consumption	AP	Average household income	-	-	-
Headley	1963	Average daily per capita water consumption	-	Household income	-	-	-
Fourt	1958	Per capita consumption	AP	Per capita income	X	Number of days of precipitation in June, July and August	-
Seidel and Baumann	1957	Water production	AP	-	-	-	-
Larson and Hudson	1951	Daily per capita residential water used	-	Net family income	-	-	-
Metcalf	1926	Municipal water use	AP	-	-	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Bartczak et al.	2009	Uniform price	-0.23 to -0.22	0.12 to 0.16	Household size: -0.35 to -0.32
Diakité et al.	2009	3-block IBT	-0.816	0.146	-
Garcia-Valiñas et al.	2009	Two-part tariffs	-0.16	-	-
Olmstead	2009	IBT (2-blocks and 4-blocks)	Unconditional elasticity from DCC model: -0.609; elasticities conditional on the choice of block: -0.292 (IV model); -0.641(DCC model)	Unconditional elasticity from DCC model: 0.1865; elasticities conditional to the choice of block: 0.683 (IV model); 0.1959 (DCC model)	-
Ruijs	2009	5-block IBT (with fixed charge for 1st block)	-0.20 (short-run); -0.28 (long-run)	0.19 (short-run); 0.28 (long-run)	-
Schleich	2009	Single price (average price)	-0.22	0.21	-
Schleich and Hillenbrand	2009	Uniform price	-0.252 to -0.23	0.355	Household size: -0.436 (regarding per capita consumption); Population age: 0.603; share of households with wells: -0.014
Arbués-Gracia et al.	2008	Uniform price	-0.129 to -0.033	0.811 to 1.286	Percentage effect of the temperature dummy variable (-5.361 to -1.779); percentage effect of central heating (-36.014 to -31.470)
Azomahou	2008	Two-part tariff	-0.354 to -0.180	0.036 to 0.096	0.264 to 0.285 (spatially lagged dependent variable)

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Basani et al.	2008	Uniform price	-0.52 to -0.41	0.68 (expenditure)	Household size: 0.056 to 0.058
Bell and Griffin	2008	Block-tariffs	-0.127	-	-
Cheesman et al.	2008	Uniform price	-0.059 (private connections) (-0.081 for households who knew the water price); -0.53 (private connections and wells); -0.44 (well water)	0.141	Household size: 0.507
Frondel and Messner	2008	-	-0.485 (price conscious households); -0.300 (others)	0.128 (price conscious households); 0.306 (others)	Household size: 0.303 (price conscious households); 0.206 (others)
Kenney et al.	2008	Fixed charge + uniform price or IBT	-0.6 (-0.75 to -0.34). During restrictions: -0.37 (-0.24 to -0.46)	-	Temperature: 0.02; precipitation: -0.04
Miyawaki et al.	2008	IBT	-1.14 to 0.18	-0.15 to 0.18	Household size: 0.17 to 0.23; Number of rooms: 0.009 to 0.14; Floor space: 0.035 to 0.079; Lagged consumption: -0.15
Nataraj and Hanemann	2008	Fixed charge + IBT (2 blocks until 1994, 3 blocks afterwards)	-	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Nauges and Berg	2008	5-block IBT plus fixed charge	-0.15 (piped water); -0.37 (piped water and other sources); -0.006 (other sources)	0.138 (piped water)	-
Reynaud	2008	-	-0.15 (peak period); -0.12 (off-peak period)	-	-
Ruijs et al.	2008	5-block IBT (with fixed charge for 1st block)	Between −0.45 and −0.50	Between 0.39 and 0.42	-
Statzu and Strazzera	2008	IBT; higher tariff for nonresidents; lower tariff for low income households	-0.161 to -0.139	0.105 to 0.199	Household size: 1.063 to 1.119; % home owners: -0.525 to -0.463; Altitude: -0.027 to -0.024
Strong and Smith	2008	Uniform price and IBT	-0.41 to -0.125	0.62	-
Xayavong et al.	2008	IBT	-1.15 to -1.06 (indoor: 0.94 to -0.70; outdoor: -1.45 to -1.30)	0.5 to 0.6	-
Babel et al.	2007	Block tariffs after minimum free allowance (10m3/month)	-0.167	-	Number of connections: 1.055; Ratio of the population to the number of university students: 0.5; precipitation: -0.21
Dahan and Nisan	2007	3-block IBT	-0.18	-	-
Fullerton et al.	2007	IBT	-1.04	-	-
Grafton and Kompas	2007	Uniform price	-0.352086	-	Temperature: 0.221793; water restrictions: 0.107878
Grafton and Ward	2007	Uniform price	-0.17	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Mansur and Olmstead	2007	IBT and uniform price	Overall indoor -0.07; overall outdoor - 0.68; arid season indoor 0.06, arid season outdoor -0.74; wet season indoor -0.10; wet season outdoor - 1.18 ("households with the largest incomes and lot sizes have the least price elastic outdoor demand" (Grafton and Ward, 2006))	-	-
Martínez-Espiñeira	2007	Fixed quota plus 3-blocks increasing tariff + sewage collection fee + treatment fee + water infrastructure fee (since 1994) + extra fee (1993-1997, "charged for the company's finances to recover from the impact of the drought.")	Short-run: -0.159 to - 0.073; Long-run: - 0.514 to -0.405	-	-
Martins and Fortunato	2007	Fixed charges (connection + sewerage charge) + IBT	-0.558	-	-
Musolesi and Nosvelli	2007	IBT	-0.47 (long-run); -0.27 (short-run)	0.181	Household size: 0.324; % of population > 65 years of age: -0.09
Nauges and Strand	2007	-	Non-tap water demand elasticities with respect to total water cost (defined as the sum of water price and hauling cost): - 0.656 / -0.579 (private tap); -0.657 / -0.542 (public tap); -0.591 (public well); -0.418 / - 0.088 (trucks).	0.231-0.299	Household size: - 0.693 to -0.350

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Olmstead et al.	2007	IBT and uniform price	-0.33 (-0.5893 para a amostra só com IBT e -0.3258 para a amostra só com preços uniformes) (unconditional elasticity vs. elasticity conditional to the consumption block)	0.13 (-0.1786 para a amostra só com IBT e 0.0432 para a amostra só com preços uniformes) (unconditional elasticity vs. elasticity conditional to the consumption block)	-
Yoo	2007	Uniform price	-0.759	0.109	Household size: 0.443
Arbués and Villanua	2006	IBT + fixed charge	ranged between -0.081 and –0.029	0.7919	Household size elasticity of the demand: 0.479
Fullerton et al.	2006	-	-	-	-
Garcia-Valiñas	2006	Fixed charge + IBT (3 blocks for households, 2 blocks for firms)	-	-	-
Gaudin	2006	DBT, IBT, uniform price	-0.37 (-0.36 for areas that do not include the information about the MP and -0.51 for areas that do)	0.3	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Hoffmann et al.	2006	Two-part tariff	Logarithmic model: -0.507 (-0.455 for owner-occupier households and -0.391 for renter households); Linear model: -0.588 (-0.607 for owner-occupier households and -0.399 for renter households)	Logarithmic model: 0.235 (0.298 for owner occupier households and 0.191 for renter households); Linear model: 0.239 (0.234 for owner-occupier households and 0.276 for renter households)	Household size: 0.169 to 0.414; Rainy days: -0.273 to -0.168; Warm days: 0.006 to 0.020; Lagged quarterly demand: -1.579 to -0.658
Jansen and Schulz	2006	3 to 6 block IBT	0.99 to -0.23	-	temperature: 0.318; household size: 0.565
Kostas and Chrysostomos	2006	-	-0.1	0.72	-
Larson et al.	2006	-	-	-	-
Mazzanti and Montini	2006	IBT	-1.33 to -0.99	0.40 to 0.71	-
Carter and Milon	2005	Fixed charge + uniform price or IBT	-3.054 (MP; knows the price; long-run) to 0.061 (AP, does not know the price, short-run)	0 to 0.255	-
Dalmas and Reynaud	2005	Uniform price	-0.41 to -0.28	0.26 to 0.41	Household size: -0.74
Garcia-Valiñas	2005	Fixed charge + IBT (3 blocks for households, 2 blocks for firms)	-0.55 to -0.46 (residential); -0.75 to -0.69 (industrial/ commercial)	0.58	-
Garcia-Valiñas	2005	Fixed charge + 4-block IBT for households and two-part tariffs for commercial/industrial	-0.11 to -0.09 (residential); -0.13 to -0.12 (industrial/ commercial)	0.39	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
García-Valiñas	2005	Two-part tariff	-0.04 (residential); -0.11 (commercial/ industrial)	0.27	-
Gaudin	2005	DBT, IBT, uniform price	-0.37 (-0.28 for areas that do not include the information about the MP and -0.51 for areas that do)	0.30	-
Hanemann and Nauges	2005	Uniform price	–0.47 to –0.29 in the high season (June-October); –0.19 to 0 in the low season (November-May)	-0.008 to 0.257	Temperature: 0.006 to 0.035; precipitation: -0.446 to -0.042
Martins and Fortunato	2005	IBT	-	-	-
Reynaud and Thomas	2005	Two-part tariff	-0.15 to -0.06	-0.17 to -0.11 (not significantly different from 0)	Precipitation: -0.09

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Reynaud et al.	2005	Flat rate, uniform price, DBT, IBT	0.02 (flat rates), -0.11 (constant unit rates), -0.25 (increasing block rates), -0.10 (decreasing block rates)	-	-
Strand and Walker	2005	IBT	-0.3 (for tap water demand) and -0.1 for non-tap water demand (-0.4 to -0.3 if all hauling costs are included)	0.02 (tap water); 0.04 to 0.08 (nontap water)	Household size: 0.06 (nontap); children (tap): 0.5 to 0.7; adults (tap): 0.8
Arbués et al.	2004	Fixed charge + IBT	-0.058 to –0.029	0.074 to 0.208	Household size: 0.734 to 0.868
Fullerton and Elías	2004	-	-	-	-
Garcia and Reynaud	2004	Fixed charge and volumetric charge	-0.2542	0.0271 (not significantly different from 0)	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Martínez-Espiñeira and Nauges	2004	Fixed quota + increasing 3-block rate	-0.13 to -0.07	0.07 to 0.13	-
Mylopoulos et al.	2004	IBT (fixed charge for the first block rate) (3 blocks in the beginning of the study period, later increasing to 6)	Marginal price-elasticity of demand is found to be an inverted U-shaped function of water consumption (between -0.721 to -0.113 for MP and between -0.923 and -0.532 for AP); higher price elasticity for intermediate consumptions; lower elasticity for lower and higher consumptions	0.127	Precipitation: -0.104; dummy for water authority employee: -0.193
Taylor et al.	2004	Flat rates, uniform price and fixed charges combined with block tariffs (IBT or DBT)	-0.297	0.382	Temperature: 0.478; Summer months: 0.364
Ayadi et al.	2003	IBT	-0.48 to -0.1	-	-
Dalhuisen et al.	2003	-	-0.35 (median of studies surveyed) -0.41 (average of studies surveyed)	0.24 (median of studies surveyed) 0.43 (average of studies surveyed)	-
Fullerton and Nava	2003	-	-	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Garcia and Thomas	2003	Fixed charge and uniform price	-0.347	-	-
Krause et al.	2003	Uniform price	-	-	-
Martínez-Espiñeira	2003	IBT (half the sample has a minimum of consumption with fixed price) (3 blocks)	-0.47 to -0.37	-	-
Nauges and Thomas	2003	Two-part tariff	Short-run: -0.26; Long run: -0.4	0.51	-
Piper	2003	-	-0.32	0.12	-
Acharya and Barbier	2002	Uniform price	-0.073 (collection and purchase); -0.067 (purchase only)	-	-
Agthe and Billings	2002	Uniform price	-0.45 (winter); -0.73 (summer)	-	-
Hajispyrou et al.	2002	Fixed charge + IBT (3 to 7 blocks); Some cases have null 1-st block prices	-0.79 to -0.39	0.22 to 0.48	-
Ipe and Bhagwat	2002	-	-0.002	0.0002	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Martínez-Espiñeira	2002	Fixed charge + uniform price or Block tariff; Free allowances	-0.17 to -0.12 (overall water demand) (up to 0.41 for different specifications)	-	-
Nauges and Blundell	2002	3-block IBT plus fixed charge	-0.36 (nonparametric model); -0.21 (OLS); -0.45 (2SLS); -0.68 (ML1); -0.33(ML2) [for ML2 the following price-elasticities are reported for the sucessive income quartiles: -0.46; -0.37; -0.29]	0.70 (nonparametric model); 0.09 (OLS; 2SLS); 0.11 (ML)	-
Pashardes and Hajispyrou	2002	Block tariffs	-0.6	0.3	-
Gaudin et al.	2001	Block tariffs	-0.47 to -0.19	0.08 to 0.28	-
Gunatilake et al.	2001	IBT (free allowance for the first 10m3)	-0.34	0.08	Difference: 0.35; household size: 0.38
Higgs and Worthington	2001	Flat rate changed to fixed charge + 2-block IBT	-	-	-
Nauges and Reynaud	2001	Two-part tariff	-0.22 to -0.08	0.01	% of recent hoouses (built after 1982): -0.12 and -0.09; % of population aged less than 20 years: 0.28; % of detached houses: -0.44 to 0; % of houses with 2 or more cars: 0.37; % of houses with bathtubs: 0.59; summer precipitation: -0.08

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Nauges and Thomas	2000	Two-part tariff	-0.22	0.09	% of population over 60: -0.22; % of single houses: -0.436; % of houses with bathtub: 0.589; % of recent houses (built after 1982): -0.119; industry activity rate of growth: 6.219
Renwick and Green	2000	Uniform price and IBT	-0.16 (overall); -0.20 (summer months)	0.25	Lot size: 0.27; temperature: 0.45; precipitation: not significantly different from zero
Rietveld et al.	2000	IBT	-1.17	0.05	-
Corral et al.	1999	Flat rates, uniform price, DBT and IBT	-0.17 to 0 (all year) and -0.30 (dry months in drought periods) to 0.14 (dry months in normal periods)	0.25 (overall); 0.545 (drought periods)	Temperature: 0.76; Precipitation: -0.016
Dzisiak	1999	Two-part tariffs (uniform price + service charge) and Multi-part tariffs (Service charge + DBT or IBT)	-0.26 (total); -0.18 (indoor); -0.34 (outdoor)	0.35 (total); 0.28 (indoor); 0.40 (outdoor)	-
Höglund	1999	Service availability charge plus uniform price or DBT	-0.122 to -0.082 (MP) and -0.264 to -0.204 (AP)	0.066 to 0.130	-
Merrified and Collinge	1999	Fixed charge + IBT	-	0.2 to 0.46	-
Pint	1999	Uniform price and IBT	-0.47 to -0.04 (summer) and -1.24 to -0.07 (winter)	-	-
Renzetti	1999	Flat-rates; constant rates and DBT	-0.124 (residential); -0.593 (nonresidential); -0.033 (sewage)	0.596 (water supply); -0.251 (sewage treatment)	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Billings and Agthe	1998	Fixed charge plus IBT	-	-	-
David and Inocencio	1998	IBT for connected households	-0.5 (-2.1 for vended water)	0.173 (0.254 for vended water)	Household size: 0.351 (0.411 for vended water)
Largo et al.	1998	IBT for connected households	-0.72	0.15	Household size: 0.866
Mattos	1998	Fixed charge with free allowances + IBT	-0.25 to -0.19	-	-
Renwick and Archibald	1998	Uniform price (until May 1989) and IBT	-0.33 (total sample); -0.53 (low income) to -0.11 (high income)	0.36	-
Agthe and Billings	1997	IBT	-0.57 (high-income) to -0.39 (middle-income); -0.51 (low-income)	-	-
Dandy et al.	1997	Two-part tariff with free allowances (fixed charge calculated as a percentage of the improved value of the property; the free allowance was obtained dividing the fixed charge by the unit price) (1991-92 introduced a fixed free allowance)	-0.86 (long-run, summer) to -0.12 (short-run, winter)	0.14 (short-run, dynamic model) to 0.49 (long-run, summer, dynamic model)	Household size: 0.04 (short-run, dynamic model) to 0.42 (long-run, winter, dynamic model)
Espey et al.	1997	Uniform price, IBT and DBT	Mean price-elasticity: 0.51 (short-run median: -0.38; long-run median: -0.64); "90% of all estimates between 0 and -0.75" (Olmstead et al. 2007)	-	-
Malla and Gopalakrishnan	1997	IBT	-0.49 to -0.162	0 to 1.370	Precipitation: -0.118 to 0.016; household size: 1.011 to 1.036

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Saleth and Dinar	1997	Fixed charge + 3-block IBT, after an initial free allowance	0.213 (AP) and -0.580 (MP)	-	Household size: 0.476
Barkatullah	1996	Two-part tariff (for the two last quarters) of multipart-increasing tariff (fixed charge + IBT)	-0.21	0.07	Difference: -0.03; Temperature: 0.04; precipitation: -0.13; Household size: 0.17
Dziegielewski	1996	Block tariffs	-0.44 to -0.05	-	-
Hansen	1996	Two-part tariff	-0.1 to -0.003	-	Energy cross-price elasticity: -0.22 to -0.21
Andrade et al.	1995	Fixed charge with free allowances + IBT	-0.24 (-0.625 [low income]; -0.165 [average income]; -0.216 [high income])	0.019	Difference: -0,796 to 0.506; Household size: 0.043
Hewitt and Hanemann	1995	2-block IBT	-1.63 to -1.57	0.15	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Bachrach and Vaughan	1994	Fixed charge with free allowances + IBT	-0.43 to -0.03	0.02	Difference: -0.09 to 0.03
Crane	1994	-	-0.48 (water vendors); -0.60 (public taps)	0.03 to 0.12	Household size: 0.06 to 0.08
Walters and Young	1994	Flat rates, uniform price and fixed charges combined with block tariffs (IBT or DBT)	-0.46 to -0.34 (metered); -0.76 to -0.72 (nonmetered)	-	-
Boistard	1993	-	-0.33 to -0.11	-	-
Nieswiadomy and Cobb	1993	Uniform price, IBT and DBT	-0.29 for DBT to -0.27 for IBT (MP), -0.64 for IBT and -0.45 for DBT (AP); -0.637 for IBT and -0.319 for DBT (other)	-0.45 to -0.22 (DBT) 0.57 to 0.63 (IBT)	Precipitation: -0.33 to 0.015, temperature: 1.43 to 2.18, household size: -0.93 to -0.27 (IBT) and 0.21 to 0.35 (DBT), conservation programme: -0.17 to -0.01
Point	1993	Uniform price and block tariffs	-0.167	-	-
Lyman	1992	Two-part tariff	Peak: -2.019 to -1.354; Off-peak: -0.512 to -0.395	0.084 to 0.147	-
Martin and Wilder	1992	Fixed charge + uniform rate	-0.60 to -0.32 (MP) and -0.70 to -0.49 (AP)	0.04 to 0.27	-
Nieswiadomy	1992	Block tariffs	-0.17 to -0.02 (MP), -0.60 to -0.22 (AP) and -0.45 to -0.29 (price perception model)	0 to 0.44	Precipitation: -0.26 to 0; temperature: 0 to 3.83; household size: 0 to 0.73

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Renzetti	1992	-	-1.193 (industrial); -0.6487 (residential, summer); -0.0137 (residential, winter)	0.9097 (residential, summer); 0.5515 (residential, winter)	0.785 (output-elasticity of industrial demand)
Stevens et al.	1992	Uniform price, IBT and DBT	-0.69 to -0.10	-	-
Woo	1992	DBT (residential); Unifrom price (commercial)	-0.384	0.278	Monthly supply hours: 0.153; net precipitation: 0; temperature: 0.01
Griffin and Chang	1991	Flat rates, uniform price, IBT and DBT	-0.476 to -0.114	0.128	Precipitation: -0.154; number of days without precipitation: 0.649
Nieswiadomy and Molina	1991	IBT (1976-1980) and DBT (1981-1985)	-0.110 (DBT); - 0.295 (IBT)	0.088 to 0.186	Lawn size: 0.147 to 0.235; weather: 0.463 to 1.744
Rizaiza	1991	-	-0.78 to -0.22	0.09 to 0.49	Household size: 0.44 to 0.73; Temperature: 0.94 to 1.26
Schneider and Whitlatch	1991	Minimum charge plus 5 DBT	-0.262 (long-run); -0.119 (short-run) (residential); -0.918 (long-run) -0.236 (short-run) (commercial); -0.438 (long-run, industrial); -0.781 (long-run) -0.438 (short-run) (government) -0.956 (long-run) -0.369 (short-run) (schools); -0.50 (long-run) -0.14 (short-run) (total metered)	0.207 (residential); 1.97 (commercial); 0.895 (government); 0.487 (school); 0.231 (total metered)	Household size: 0.306 (residential); 0.385 (commercial); 0.683 to 0.968 (government); 0.407 (school); 0.26 to 2.51 (total metered). Housing composition: -0.66 (residential); -0.93 (total metered). Summer precipitation: 0.145 (residential); -0.169 (total metered)

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Billings	1990	IBT	-0.717 to -0.565 (long-run); -0.50 to -0.36 (short-run)	0.296 to 0.300	Household size: 0.136 to 0.221; Temperature: 0.516 to 0.742; Precipitation: -0.053 to -0.019
Griffin and Chang	1990	Block tariffs	-0.19 to -0.16 in th winter and -0.38 to -0.37 in the summer (AP)	0.48 (winter); 0.30 (summer)	-
Miaou	1990	Flat fee for first m3 + DBT	-0.354 to -0.174	-	Precipitation: -0.098 to -0.056; summer temperature: 0.320 to 0.410; average monthly temperature: 1.167
Mu et al.	1990	Uniform price, IBT and DBT	-	0.07	Collection time: -0.16; years of formal education: 0.06; proportion of women: 0.26
Billings and Day	1989	Fixed charge + uniform rate or IBT and seasonal rate	-0.72 (overall price-elasticity); -0.52 (MP) and -0.70 (AP)	0.31 to 0.36	Difference variable: -0.21; temperature: 0.63 to 0.81; Summer precipitation: -0.06; publicity about water problems: -0.05 to -0.04; household size: 0.16 to 0.48; aged 65 or older: -0.13 to 028
Moncur	1989	Uniform price and DBT	-0.05	-	-
Nieswiadomy and Molina	1989	IBT (1976-1980) and DBT (1981-1985)	-0.86 to -0.36	0.11 to 0.24	Lawn size: 0.26 to 0.38; house size: 0.18 to 0.27; weather: 0.58 to 0.73

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Weber	1989	-	-0.25 to -0.1	-	-
Wilson	1989	-	-0.5	0.6	Moisture deficit: 1.3
Nieswiadomy and Molina	1988	IBT	-	0.13 to 0.31	-
Palencia	1988	IBT (first blocks have a charge which is fixed within the block and increasing from one block to the next)	-0.287	0.542	-
Thomas and Syme	1988	Flat rates (until 1977/78) and uniform rates with free allowances (after 1978/79)	TS: -0.43 to -0.01; CV: -0.18 (total); -0.04 (indoor); -0.31 (outdoor) (decreasing with income level, increasing with household size)	0.2	-
Agthe and Billings	1987	IBT + seasonal pricing	-0.565 (low income) to -0.397 (high income)	-	-
Billings	1987	Fixed charge plus IBT	-0.5 to -0.06	-	-
Frerichs et al.	1987	Block tariffs	-0.21 to -0.17 (MP) and -0.27 to -0.19 (AP)	0.6	Household size: 0.5; proportion of youth: -0.43

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Moncur	1987	Uniform price and DBT	Short-run: -0.517 to -0.032; Long-run: -0.683 to -0.1	0.038 to 0.080	-
Schefter	1987	IBT plus fixed charge	-0.13	0.65	-
Agthe et al.	1986	Service availability charge plus IBT	-0.624 (long-run); -0.364 (short-run)	-	Difference: -0.247 (long-run); -0.136 (short-run)
Chicoine and Ramamurthy	1986	DBT	-0.47	-	-
Chicoine et al.	1986	DBT	-0.42 to -0.22	0.01 to 0.14	-0.29 to -0.27 (second price-related variable)
Deller et al.	1986	DBT	-1.12 to -0.36 (average of -0.76)	-	-
Martin and Thomas	1986	Service charge + IBT (Phoenix and Tucson); Service charge + Uniform rate after initial free allowance (Perth); Uniform rate (Coober Peddy and Kuwait)	-0.50	-	-
Williams and Suh	1986	Block tariffs	Residential: -0.484 to 0.179; Commercial: -0.360 to -0.141; -0.976 to -0.438 (industrial)	0.579 to 0.972	Temperature: 0.02; precipitation: -0.19 to -0.09; industrial output: 0.18 to 0.30
Al-Qunaibet and Johnston	1985	-	-0.976 to -0.771	-0.012 to 0.211	-
Cochran and Cotton	1985	Flat fee for first m3 + DBT	-0.40	0.58	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Schefter and David	1985	Block tariffs	-0.127 to -0.109	-	-
Jones and Morris	1984	DBT, IBT (up to 4 blocks) and uniform prices	-0.44 (log-log model) to -0.14 (linear model)	0.40 to 0.55	Household size: 0.09 to 0.17
Young et al.	1983	Uniform price (1974-1978); IBT (1979)	-	-	-
Billings	1982	IBT	-0.66 to - 0.56	0.0521 to 2.14	Difference: -0.087 to -0.075; Sewer charge: 0.101
Hanke and de Maré	1982	Uniform price	-0.15	0.11	Number of adults: 0.13; Number of children: 0.05; precipitation: -0.21
Howe	1982	Uniform price and DBT	-0.568 to -0.427 (summer) and -0.06 (winter)	-	-
Ford and Ziegler	1981	DBT	-1.613 to -0.853 (estes valores estão errados porque são os coeficientes na equação semilogarítmica)	-	-
Foster and Beattie	1981	DBT	-	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Agthe and Billings	1980	IBT	Short-run: -2.226 to -0.179. Long-run: -0.705 to -0.266	Short-run: 1.33 to 7.829. Long-run 1.70 to 2.77.	Difference: Short-run: -0.412 to -0.087. Long-run: -0.149 to -0.119.
Ben-zvi	1980	DBT	-0.73 (non-industrial); '-0.79 (winter nonindustrial); -0.82 (summer, nonindustrial); -2.42 (food industry); -0.56 (lumber and paper); -1.47 (chemicals); -0.15 (petroleum); -1.13 (stone and clay)	-	-
Billings and Agthe	1980	Fixed charge plus IBT	From -0.267 to -0.45	1.68	Difference: From -0.30 to -0.123; Sewer charge: 0.0897
Carver and Boland	1980	Uniform price and block tariffs	Nonseasonal: Short-run: -0.05 to -0.02; Long-run: -0.7 to -0.02;: Seasonal: -0.11 to -0.10 in the short-run and 0.11 in the long-run	-	-
Cassuto and Ryan	1979	-	-0.39 to -0.14	-	-
Colander and Haltiwanger	1979	Flat fee for first m3 + DBT	-0.14 to 0.09	-	Precipitation: -0.21 to -0.04
Danielson	1979	DBT	-0.272 (total); -0.305 (indoor) and -1.38 (outdoor)	0.334 to 0.363	Household size: 0.74; precipitation: -0.018 (total); -0.206 (outdoor): temperature: 0.316 (total); 5.141 (outdoor)
Foster and Beattie	1979	DBT	-0.76 to -0.27	0.6274	Precipitation: -0.0403; numer of persons per meter: 0.3026
Camp	1978	-	-0.35 to -0.03	0 to 0.14	-
Gibbs	1978	DBT and uniform price (some cases with flat rates for the first m3)	-0.51 (MP) and -0.62 (AP)	0.51 to 0.8	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Katzman	1977	Uniform price	-0.1 to -0.2	0 (low income families); 0.2 to 0.4 (higher income families)	-
Clark	1976	-	-0.63 to -0.17	-	-
Grunewald et al.	1976	-	-0.92	-0.14 (not significantly different from 0)	-
Morgan and Smolen	1976	-	-0.65 to -'0.43	0.24 to 0.67	-
Andrews and Gibbs	1975	DBT; free first block after paying a fixed cahrge	-0.62 (AP); -0.51 (MP)	0.51	-
Attanasi et al.	1975	Block tariffs	-2.19 to 0.81 (residential); -3.02 to -1.08 (commercial); -1.33 to -0.23 (industrial)	0.08 to 0.21 (residential); 0.02 to 0.10 (commercial)	Output elasticity: 0.01 to 0.21 (industrial)
Batchelor	1975	Uniform price	-	0.38 to 0.93	-
Darr et al.	1975	-	-	0.17 to 0.60	Household size: -1.01 to -0.28
Hogarty and MacKay	1975	Fixed charge plus uniform price with free allowance or DBT	-0.86 to -0.56	-	-
Morgan	1974	Two-part tariff	-0.49	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Grima	1973	DBT plus fixed charge	-1.07 (summer) to -0.75 (winter) (variable price); -0.35 (summer) to -0.24 (winter) (fixed bill)	0.48 to 0.56	Household size: 0.59 to 0.63
Morgan	1973	Uniform price	-	0.33 to 0.31	Household size: 0.25 to 0.57
Young	1973	Flat fee for first m3 + DBT	-0.65 to -0.41	-	Precipitation: -0.14 to -0.03
Wong	1972	Flat rate and uniform rate	-0.283 to -0.018 (time-series); -0.817 to -0.257 (cross-section)	0.195 to 0.258 (time-series); 0.476 to 1.025 (cross-section)	Summer temperature: 0.410 to 1.257
Hanke and Davis	1971	Block tariffs	-0.10 (residential indoor); -1.57 to -1.25 (residential outdoor); -0.10 (commercial/ industrial)	-	-
Hanke	1970	Initial flat rate changed to a uniform price after metering is universally installed	-	-	-
Turnovsky	1969	Uniform price	-0.406 to -0.049 (residential); -0.839 to -0.473 (industrial)	1.00 to 2.39	% of population <18: 0.73 to 1.18
Meroz	1968	Flat rates and volumetric rates	-0.53 to -0.43	0.33 to 0.41	-
Conley	1967	-	-1.09 to -1.02	-	-
Howe and Linaweaver	1967	Uniform price and DBT	-0.23 (indoor) -1.57 to -0.7 (outdoor)	0.4 to 1.5	-
Bain et al.	1966	-	-1.099	-	-
Flack	1965	-	-0.61 to -0.12	-	-

Authors	Year of publication	Type of tariff structure	Price-elasticity	Income-elasticity	Other elasticities
Gardner and Schick	1964	-	-0.77	-	-
Gottlieb	1963	-	-0.39 to -1.23	0.28 to 0.89	-
Headley	1963	Uniform price	-	0 to 0.37	-
Fourt	1958	-	-0.386	-	-
Seidel and Baumann	1957	Flat rates and volumetric rates	-1 to -0.12	-	-
Larson and Hudson	1951	-	-	0.7	-
Metcalf	1926	-	-0.65	-	-

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