ECONOMIC DISCUSSION PAPERS

Efficiency Series Paper 4/2013

Responses to changes in domestic water tariff structures: An analysis on household-level data from Granada, Spain

María Pérez Urdiales, María A. García-Valiñas, Roberto Martínez-Espiñeira

Departamento de Economía

Universidad de Oviedo

Available online at: http://economia.uniovi.es/investigacion/papers

Responses to changes in domestic water tariff structures: an analysis on household-level data from Granada, Spain

María Pérez Urdiales*
Oviedo Efficiency Group, University of Oviedo

María A. García-Valiñas
Oviedo Efficiency Group,
University of Oviedo, Spain, and LERNA, Toulouse, France

Roberto Martínez-Espiñeira
Department of Economics
Memorial University of Newfoundland

Abstract

A problem in estimating water demand functions is the presence of unobserved individual heterogeneity, as estimating a common demand function for every observation may not be correct in the sense that the estimated water function is unlikely to represent consumer's behavior. We implement latent class models to define consumers groups with similar preferences while we estimate heterogeneous water demand functions. Our analysis exploits data on residential water demand and consumers' preferences from a household-level panel obtained by combining information from a survey of 1465 domestic users in the city of Granada and bimonthly price and consumption data supplied by this city's water supplier from the period 2009-2011.

JEL-Classification: Q21, Q23 and Q25
Keywords: water demand, water pricing, panel data, household microdata, latent class analysis.

*Corresponding author: University of Oviedo, Facultad de Economía y Empresa, Av. del Cristo s/n 33006, Oviedo, Spain. E-mail: perezumaria@uniovi.es

1. Introduction

Human demand for water is expected to increase in the next years as the world population is also predicted to grow from 6.9 billion in 2009 to 8.3 billion in 2030 and 9.1 billion in 2050 (UNDESA, 2009). This population growth and the augmenting tendency to urbanization will lead to a higher water demand and at the same time, a lower ability of ecosystems to provide conventional and cleaner supplies (The World Bank, 2012). Although there are different types of tools available to deal with imbalances between water supply and demand, the use of pricing policies is a key type of strategy available to regulators concerned with minimizing the welfare effects of water demand management. This is because pricing policies are expected to result in lower levels of efficiency losses than the alternatives (Roibás et al., 2007). Therefore, we will focus on the effects of pricing policies to manage demand. As coping with increasing water scarcity becomes a priority for regulators, water price is expected to increase in the future. This may have substantial implications for consumers, whom can be affected differently by changes in residential water prices. In this sense, the analysis of residential water demand at the household level is fundamental for policy decision-making.

When analysing the effect of changes in residential water prices, addressing the unobserved individual heterogeneity is a critical issue as water demand functions rely on unobservable different preferences. However, the most common methods for accounting unobserved individual heterogeneity are unsatisfactory.

In this paper we implement a Latent Class Analysis in order to model the heterogeneity of water demand functions in a population. This technique allows us to identify a finite number of consumer "classes" that respond in a similar way to the drivers of demand. Unlike other techniques, such as Cluster Analysis, which permit the identification of different groups in two stages, this methodology is a one-stage technique. Since it is a data-driven methodology, there is no need to have prior knowledge about these classes; the consumers demand and the probability of membership of a particular group are estimated simultaneously. This semiparametric application also offers the advantage of characterizing the demand function in terms of elasticities and substitution relationships and allows us to analyse the effect of a change in the price structure.

Our application exploits a panel dataset from Granada (Spain), which contains information on bimonthly water consumption and prices for the period 2009-2011, as well as on socioeconomic variables and self-reported water conservation habits for 2011, which can be useful to control for individual heterogeneity. This data set is of particular interest because there was a change in the price structure in the city of Granada in 2011. The results provide important information for regulators by identifying five different residential water consumer profiles. We also derive some interesting results on the analysis of the change in the price structure that took place in 2011.

The paper has the following structure. In Section 2, we discuss the related literature. Section 3 describes the tariff structure in the city of Granada, paying special attention to the change in 2011. Section 4 presents the econometric model. Section 5 describes the data. Estimation results are presented in Section 6 while Section 7 concludes summarizing the main results.

2. Literature Review

Water demand estimation is a fundamental ingredient for an appropriate management of a resource that is becoming increasingly scarce. Consequently, the literature on residential water demand is vast. Several studies have surveyed the estimation of water demand. For example, Arbués et al. (2003) focus on different modelling approaches and data sets; Dalhuisen et al. (2003) include a meta-analysis of price and income elasticities; Worthington and Hoffman (2008) provide a survey of model specification and results; and Nauges and Whittington (2010) review the literature analysing household residential demand in less developed countries.

An extensive literature on residential water demand aims to control for the presence of unobserved individual heterogeneity. However the common methods to address heterogeneity seem to perform poorly in this context. A common approach has been to include household fixed effects to control for unobserved individual heterogeneity. Pint (1999) uses a fixed effects model to estimate household responses to water price structure changes in California. The results show that water consumption decreased after the change in the price structure. Fixed effects model is an improvement upon OLS, but it does not control for price endogeneity. Worthington et al. (2009) use fixed and random effects models to estimate residential water demand for several councils in Queensland and then compared those estimations to an OLS regression.

An alternative approach is to include group dummy variables, which indicate socioeconomic and demographic characteristics that can capture differences in individual's preferences, in the demand function. Renwick and Green (2000) incorporated irrigation dummy variables into the demand equation to account for differences in outdoor water use. Krause (2003) investigated consumer heterogeneity in water demand using a set of experiments and a survey. First they included group dummy variables in the demand function and then estimated dissagregated demand functions for three consumer types.However, including these variables in the demand function only accounts for differences in the intercept,the slope remaining unchanged.

Several studies have accounted for heterogeneity in the price structure by estimating Discrete/Continuous Choice (DCC) models. For instance, Hewitt and Hanemann (1995) estimate residential demand for water under increasing block rates using household level data from Denton, Texas and their results suggest that water demand is more price-elastic than those estimated using other methodologies. Olmstead et al. (2007) also use a DCC model to estimate the price-elasticity of water demand for households in urban areas of the United States and Canada. Olmstead (009b) compares random effects, Discrete-Continuous Choice and Instrumental Variables estimates on water demand of increasing block prices, and concludes that, when heterogeneity is driven by household preferences, the DCC model is preferred over IV and RE, price elasticity is biased, but less than with the other models. Despite DCC model being theoretically more appropriate, price elasticity estimates are similar to the central tendency of previous estimates in the literature. Moreover, this model assumes that consumers have perfect knowledge of price structure and such assumption can not be made for residential water demand in Granada [1]

Many studies use two stage techniques such as Cluster Analysis to identify different groups of consumers. Renwick and Archibald (1998) analyse the effect of demand side policies by clustering groups of consumers in terms of income. Ruijs et al. (2008) estimates a linear demand function in the Metropolitan Region of Sao Paulo for the period 1997-2002 and, using the demand function, welfare and distribution effects are evaluated for five income groups. Mansur and Olmstead (2012) divide the sample into four sub-groups based on income and lot size in order to compare different price elasticities for indoor and outdoor water demand. However, these techniques make an *ad hoc* selection to the membership, which is highly sensible to arbitrariness.

Latent Class Models (LCM) have attracted increased attention lately to control for unobserved heterogeneity. A number of studies use this methodology to analyse demand in other economic fields such as health economics (Deb and Trivedi, 2002; d' Uva, 2006; Ayyagari et al., 2013; Hyppolite and Trivedi, 2012), cultural economics (Boter et al., 2005; Fernandez-Blanco et al., 2009; Grisolía and Willis, 2012) or transport (Hensher and Greene, 2003; Shen et al., 2006; Shen, 2010; Hess et al., 2011; Greene and Hensher, 2013).

There are several applications to LCM to environmental economics. For example, Scarpa et al. (2005) compare the use of the mixed logit random parameter model with the use of Latent Class Analysis to model the choice of water utility by the consumer. Patunru et al. (2007) implement this methodology to investigate the willingness-to-pay for contaminant cleanup of homeowners in Waukegan, Illinois. Scarpa et al. (2007) study different groups in the demand for hiking in the eastern Italian Alps, discussing that it is fundamental to asses heterogeneity when analysing expected consumers surplus, predicted visitation and response to access fees. Campbell et al. (2011) identify heterogeneous groups of respondents that were asked about the willingness-to-pay for improvements in four rural landscapes in the Republic of Ireland. However, as far as we are aware there have been no applications as yet to residential water demand functions.

As mentioned in the introduction section, it is important to account for consumers heterogeneity to analyse the effect of a change in the price structure. Several papers have compared price elasticities across price structures in different municipalities, however differences in terms of elasticities may be due to the underlying heterogeneity among municipalities. Rinaudo et al. (2012) analyse residential water demand in the South of France, a very heterogeneous area regarding water pricing structures. After several simulations, results suggest that increasing block pricing structure (IBP) is the most appropriate tariff in terms

[1] Only 15,53 % of households chosen for the study are actually informed about the price structure.

of redistributive efficiency. Worthington et al. (2009) model residential water demand in Queensland where water consumption is charged using a variety of price structures for the period 1994-2004. However, by 2002-2003, most of the larger local governments in Queensland had chosen two-part tariffs, as opposed to smaller local governments. Therefore, change in price structure is analised for part of the municipalities. The results show that the average level of consumption is higher under two-part tariffs, indicating that the change in price structure was not optimal.

To the best of our knowledge, there is only one previous work which presents a change in the price structure similar to the one exploited in this paper. Martínez-Espiñeira and Nauges (2004) study residential water demand in Seville (Spain) for the period 1991-1999, having a slight change in the block size from 1996. Water demand is modelled using Stone-Geary utility function that allows to identify a threshold of water that is insensitive to price, however the change in the block is not directly analysed.

3. Residential Water Tariffs in Granada

The water pricing structure in Granada is based on increasing block prices (IBP). In this case, the tariff[2] also includes a fixed water service fee that must be paid regardless of the level of use and a set of increasing block prices. As can be seen in Table 2, the price structure in Granada remained unchanged between 2009 and 2010, but in 2011 the size of the price blocks was altered.

The fixed component of the tariff includes a water supply fee, a sewage collection fee, and a treatment fee and, from 2009 to 2010, a drought surcharge. Additionally, in 2011 a water tax collected on behalf of the Regional Government was incorporated to the tariff.

The evolution of the prices in each block is shown in Table 1 (with nominal figures deflated using the official consumer price index at provincial level, with 2011 being the current base year).

Table 1: Evolution of prices 2009-2011 (€/m^3)

Year	Block 1	Block 2	Block 3	Block 4	Block 5
2009	0.9798	1.9130	1.9310	2.4451	2.7356
2010	1.0318	1.9365	1.9545	2.5411	2.9137
2011	0.9731	1.3536	2.3534	3.4347	-

The tariffs in Granada were reviewed annually. Block prices were asjusted upwards from 2009 to 2010 but, as we mentioned above, the price structure remained unchanged. However, in 2011 the rate schedule also changed. The rate schedule is described in Table 2.

[2]The tariff also includes discounts to those who are unemployed, retired, or have a certain minimum number of dependants.

Table 2: Evolution of the size of pricing blocks (m^3)

Blocks	2009-2010	2011
Block 1	0-8	0-2
Block 2	8-10	2-10
Block 3	10-16	10-18
Block 4	16-30	>18
Block 5	>30	-

As water becomes increasingly scarcer in the South of Spain, water supply managers look to pricing as a water conservation tool.As stated above, Granada experienced a change in the price structure that resulted in a decrease in average water consumption, but also an increase in the average total bill (Table 3).

Table 3: Evolution of the average total bill (€/2-months) and the average quantity of water consumed (€)

Blocks	2009	2010	2011
Water consumed	15.4939	16.0069	15.2579
Total bill	44.3969	45.0625	49.1680

4. Methodology

From a methodological point of view, latent class models are proposed to identify different groups of consumers with similar preferences using observable variables and self-reported data from the survey.

In a latent class model, we assume that the sample of individuals is drawn from a population that is a finite mixture of C distint subpopulations (Cameron and Trivedi, 2005) such that:

$$f(y_i|\theta;\pi) = \sum_{j=1}^{C} \pi_j f_j(y_i|\theta) \qquad i = 1, ..., n \tag{1}$$

where π_j is the probability of choice j of individual i ($\sum_{j=1}^{C} \pi_j = 1$ and $\pi_j \geq 0$ $j = 1, ..., C$). The membership probabilities (π_j) are considered constant[3] across observations and are estimated simultaneously with the other parameters.

[3]Membership probabilities can be further parameterized as a function of covariates using, for example, a logit function. However, if separating information is not available, extension of the model may be fraught with identification problems (Deb and Trivedi, 2002)

The mixture density in the normal mixture for individual i, i=1,...n is given by the following:

$$f(y_i|\theta;\pi) = \sum_{j=1}^{C} \pi_j \frac{1}{\sqrt{2\pi\sigma_j^2}} exp(-\frac{1}{2\sigma_j^2}(y_i - x_i\beta_j^2)) \tag{2}$$

Therefore, in order to choose among the different models, one must assess ex post their performance. Although there is no a priori need to sort individuals among classes, a key choice the researcher must make involves the number of the classes to consider. Models based on different numbers of classes will result in different degrees of goodness of fit. In order to evaluate the models, we use two different information criteria: the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC).

Once the model is estimated, we use the parameter estimates to compute the posterior probabilities of belonging to each latent class:

$$Pr[y_i \epsilon c|x_i;y_i;\theta] = \frac{\pi_c f_c(y_i|x_i;\theta_c)}{\sum_{j=1}^{C} \pi_j f_j(y_i|x_i;\theta_j)} \qquad c = 1,...,C \tag{3}$$

Latent class models have two main advantages with respect to other techniques such as Cluster Analysis, which permits the identification of different groups in two stages. First, unlike other two-stage techniques that feature an exogenous or *ad hoc* selection of the membership, this approach allows a data-determined and probabilistic assignment of the consumers across the groups, which avoids arbitrariness and sample selection bias. Additionally, mixture models can account not only for intercept but also slope heterogeneity across different groups of consumers, which represents an improvement over other techniques such as fixed effects and random effects models that only capture individual-specific effects in the constant term.

Latent class model estimation simultaneously models the demand function and classifies individuals into different consumers groups.

Finally, in order to examine the determinants of class membership, we use a multivariate generalization of the fractional logit model proposed by Papke and Wooldridge (1996), that is, a quasi-maximum likelihood estimate using the following log likelihood and conditional mean:

$$l_i(\beta) = \sum_{g}^{G} y_{ig} log K_g(x_i, \beta) \tag{4}$$

$$K_g(x_i) = \frac{e^{x'_{ig}\beta}}{\sum_g^G e^{x'_{ig}\beta}} \tag{5}$$

where $0 \leq y_{ig} \leq 1$ and $\sum_g^G y_{ig} = 1$

This methodology models a set of dependent variables (or multiple fractional responses), that each of them ranges between 0 and 1 and they add up to 1. Therefore, we analyse the determinants of class membership by regressing the estimated posterior probabilities on a set of variables related to behavioral measures.

5. **Data description**

Our dataset comprises an unbalanced panel consisting of bimonthly observations corresponding to 1,465 households in the city of Granada covering the period 2009 to 2011. The data come from two sources.

The first source of information consists of water consumption and water tariffs data on a random and representative sample of urban households in the city of Granada, provided by EMASAGRA, the company in charge of water supply and sewage collection in Granada.

The second one is a 2011 survey of these households,[4] who were questioned about socioeconomic characteristics (occupation, household size), housing characteristics (size, equipment), attitudes towards the environment, and conservation habits.Table 4 shows some descriptive statistics for the variables included in the demand model. The variables used in our demand specification were:

1. Water consumption (explained variable): Daily household water consumption, in cubic meters, is calculated by dividing total consumption by the number of days in the relevant billing cycle in order to account for the slight differences in the exact frequency of billing. Arbués and Villanúa (2006) also chose daily consumption as the dependent variable in the estimation of residential water demand in Zaragoza, since the periods between two readings oscillated over a wide range Olmstead (009b).

2. Price ($MagcP_{t-1}$ and *difference*): in order to correct for the bias associated with the simultaneous determination of price and the block of consumption, we include an instrumental marginal price in the demand function. That is, we perform a modification of the approach in Billings (1982), whereby we generate a constant marginal price and a difference variable by regressing the current amounts of the individual consumers' bills (TB_i) against their respective water quantities (Q_i) separately for each year and discount type but also for each neighborhood, i.e. we use a grouping approach (Grafton et al., 2011) since we expect that consumers within the same neighborhood may have a similar perception of the price, yielding:

[4]Data on water consumption and water tariffs was merged with survey data. Since the survey was carried out in 2011, we only have information related to socioeconomic characteristics of that year. However, since these variables are usually time invariant, we consider them applicable to the period 2009-2011.

$$TB_i = \alpha + \beta Q_i + u_i \tag{6}$$

where u_i is the residual term.
This instrumental marginal price is the slope of the estimated function and the Nordin-difference variable is the intercept. Therefore, by construction, the instrumental price allows for some variation across individuals and time. Once these variables are constructed, we select the one-period lagged marginal price. Since prices change every year, the one-period lagged price captures this change in the second two-month period every year.

3. Income (*highincome*). Household income was recorded as an ordered categorical variable, with households belonging to one of the following intervals (in Euros/month): [0-1100]; [1101-1800]; [1801-2700]; [2701-3500]; [3501-$+\infty$]. It would not be appropriate to use the interval categories as if they were values of a continuous variable. Usually, one would construct a set of five binary indicators of income level and introduce four in the model. However, because we did not seem to have enough sample variability to estimate all four corresponding parameters, we simplify our original income variable into a binary indicator of relatively higher income. In particular, we create a binary variable that identifies the richer households (those falling in the two highest income categories).

4. Household composition (*members*). Household size, defined as the number of members living in the household, is expected to be positively associated with water demand. According to Barberán et al. (2000), an increase in water consumption is frequently less than proportional to an increase in the number of members living in the household or population, therefore scales economies in water demand should be expected.

5. Ownership (*owner*). An indicator of home ownership is included as homeowners are expected to have more incentives than tenants to make investments in water-saving devices in the property as shown by Grafton et al. (2011).

6. Water conservation habits (*habits*). As shown in Beaumais et al. (2010), a water habit index was constructed by calculating the mean score on the answers related to the values of water use/conservation habits that were asked in the survey (possible answers were 1 = yes or 0 = no).

7. Seasonal effect (*summer*). In order to capture a seasonal effect, we include a binary indicator that takes value 1 for summer months (defined as May throught August) and 0 otherwise.

As stated in Section 4, in order to examine the determinants of class membership, we regress the posterior probabilities on a set of variables. As Russell and Fielding (2010), we follow Stern (2000)) for guidance on which variables to consider. Therefore, the determinants of different water use behaviors are categorized into four types of causal variables:

1. Attitudinal factors. According to the value-belief-norm theory (VBN), "the general predisposition to act with proenvironmental intent can influence all behaviors an individual considers environmentally important" (Stern, 2000). Therefore, the general attitude towards the environment may influence water use behaviors. We include a binary indicator (*enviro*) that takes value 1 if at least one member of the household has collaborated with an association for environmental defense and 0 otherwise.

2. Personal capabilites. These causal variables include knowledge and skills that may facilitate conservation behaviors and also sociodemographic variables. In the estimation we consider two binary variables related to the knowledge of the existence of an environmental campaign (*campaign*) and the knowledge of the price structure (*tariff*). We also include education attaintment levels (*education*) as we can expect that those with a higher level of education may have greater awareness of the need for water conservation.

3. Habits and routines. Automatic processes such as habits and routines may guide behaviors, therefore, examining the role of habits and routines is fundamental for the analysis of water use behaviors. As people of different ages may have different habits and routines, we include variables reflecting the proportion of members over 65 (*old65*) and those under 16 (*young16*). On the one hand, we can expect households with a higher proportion of younger members to have a higher water consumption due to more frequent laundering, more frequent showers, and use of water-intensive outdoor activities. On the other hand, retired people might be more frugal but are also more likely to devote more time to activities that involve water use, such as gardening, and simply more likely to spend more time at home.

4. Contextual factors. Physical infraestructure and technical facilities are also closely related to human behavior. We include a categorical variable that accounts for the number of water efficient electrical appliances in a house (*electeff*).

In order to capture changes in consumers' preferences along the period, we include time dummy variables (*year2010, year2011*) that control for unobserved factors mainly affecting price and the change in price structure. We also include a dummy variable for the sumer months (*summer*) and the interaction of the summer dummy variable with the dummy variable for 2011 (*summer2011*) to control for seasonal effects.

Table 4: Summary statistics

Variable	N	Mean	Std. Dev	Min	Max
daily	21050	0.2571	0.1478	0.0159	1.0690
difference	21050	0.4436	1.2555	-22.6907	29.5233
highincome	21050	0.1910	0.3931	0	1
MagcP$_{t-1}$	21050	1.2407	0.1539	0.1974	2.2842
members	21050	2.6813	1.2139	1	9
owner	21050	0.7468	0.4349	0	1
habits	21050	0.6156	0.1610	0	1
summer	21050	0.3493	0.4768	0	1
enviro	21050	0.1207	0.3258	0	1
campaign	21050	0.5359	0.4987	0	1
tariff	21050	0.3408	0.4740	0	1
education	20535	3.5861	1.2201	1	5
old65	21050	0.3325	0.4276	0	1
young16	21050	0.0406	0.1243	0	0.7778
electeff	21050	0.7682	0.8288	0	2
year2010	21050	0.3492	0.4767	0	1
year2011	21050	0.3623	0.4807	0	1
summer	21050	0.3497	0.4767	0	1
summer2011	21050	0.1217	0.3270	0	1

6. Results

In order to select the model with the number of classes that fits best the data, we estimated several latent class models changing the number of classes and compared the resulting likelihood-based model selection criteria, such as the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), as stated in the methodology (see Section 4). These results, reported in Table 5, show that the Latent Class Model is a superior specification to the OLS model, which forces all consumers to respond to the same pattern in terms of their water demand.

The selection criteria yield different recommendations. The BIC suggests that the 5-class model fits the distribution better, but the AIC suggests that the 6-class model is best. Since the difference in terms of likelihood-based criteria is relatively small and one additional class represents only 2.27% of the population, we chose the 5-class model as the most accurate for capturing consumer heterogeneity. The results confirm that household heterogeneity is significant and that there seem to be five distinct residential water consumer profiles in Granada for the period 2009-2011, rather than the unique one assumed by the conventional OLS approach.

Table 5: Selection criteria for several models

Model	Log likelihood	Degrees of freedom	Akaike information criterion	Bayesian information criterion
single class	11160.15	9	-22302.29	-22230.7
2-class	12640.96	21	-25239.92	-25072.87
3-class	12956.31	32	-25848.61	-25594.07
4-class	13129.63	43	-26173.26	-25831.21
5-class	13284.12	54	-26460.24	-26030.69
6-class	13324.02	65	-26518.04	-26000.99

Next, in Table 6, we present the results of the 5-class model. We also report the results of the OLS model, i.e., single-class model that will be used to analyse the importance of household heterogeneity.

First, the estimation of the single-class model shows that the demand is price inelastic, as shown in Table 7. However, turning to the 5-class model we find that for the first class (but the smallest group, containing just 3.02% of the sample) price has no significant impact on residential water demand. In contrast, for the other classes, price is significant but the price elasticities are different among the classes, the second class being the one with the most elastic water demand. Therefore, this heterogeneity in terms of price elasticities is masked when estimated through a single-class model. To allow for the possibility that price elasticity differs between 2009-2010 and 2011, that is, between the period before and after the change in the price structure, we include the interaction involving a dummy variable for 2011 and the lagged marginal price. Table 7 shows that water demand becomes more inelastic in the single-equation estimation. By contrast, when we estimate the 5-class model, the change in price elasticity is not significant for the first and the second class, that is, the classes with the lowest and the highest water average consumption respectively.

Another important issue in the estimation of water demand functions is the inclusion of the difference variable in order to capture the income effect imposed by the increasing block rate structure. As expected, the estimated coefficient of the difference variable in the single equation estimation is negative and statistically significant. However, in the 5-class model, this coefficient is significant just for the forth and the fifth class. This result is in line with previous studies that have reported the effect of the difference variable as non-significant (Arbués et al., 2003).

When estimating a single-class model, we find that the high-income indicator has a negative and significant impact on water demand. When we estimate the 5-class model, the high-income variable also has a negative significant effect on demand for the first, second and fourth classes. This negative effect may be reflective of water conservation measures resulting from the investment in water-saving devices. The income variable coefficients corresponding to the third and

Table 6: Estimated water demand models

	Model 1 (OLS)	Model 2 (LCM)				
	OLS	Class 1	Class 2	Class 3	Class 4	Class 5
constant	0.3490***	0.0277**	0.9831***	0.1408***	0.4547***	0.2722***
	(21.28)	(1.97)	(10.82)	(4.2)	(9.37)	(17.57)
$MagcP_{t-1}$	-0.1264***	-0.0027	-0.3661***	-0.0678***	-0.1500***	-0.0982***
	(-9.42)	(-0.25)	(-5.34)	(-2.65)	(-4.23)	(-7.85)
$MagcP2011_{t-1}$	0.0137***	0.0004	0.0136	0.0109**	0.0153**	0.0138***
	(5.02)	(0.18)	(0.91)	(2.29)	(2.18)	(5.09)
difference	-0.0052***	0.0001	-0.0030	-0.0024	-0.0103***	-0.0046***
	(-3.74)	(0.06)	(-1.18)	(-0.87)	(-4.47)	(-3.84)
highincome	-0.0153***	-0.0048**	-0.0839***	0.0038	-0.0275***	-0.0034
	(-6.61)	(-2.49)	(-4.94)	(1.08)	(-4.49)	(-1.14)
members	0.0311***	0.0016**	0.0332***	0.0096***	0.0430***	0.0309***
	(34.61)	(2.43)	(6.87)	(6.6)	(22.54)	(17.71)
owner	-0.0071***	0.0041**	-0.0509***	-0.0008	-0.0196***	0.0043
	(-2.81)	(2.01)	(-3.62)	(-0.24)	(-3.37)	(1.41)
habits	-0.0312***	0.0003	-0.0642*	0.0256**	-0.0442***	-0.0453***
	(-4.87)	(0.07)	(-1.81)	(2.2)9	(-3.69)	(-6.08)
summer	0.0127***	0.0057***	-0.0241*	0.0238***	0.0115***	0.0141***
	(6.26)	(3.1)	(-1.86)	(8.52)	(2.6)	(5.83)
observations	21050	21050	21050	21050	21050	21050
mean posterior probability		0.0302	0.0726	0.1459	0.3037	0.4477
average water consumed (m^3/2-month)		1.7946	39.2275	5.9295	23.8949	13.1578

Robust t-statistics are in parentheses

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

Table 7: Price elasticities of demand

Model		Price Elasticities	
		2009-2010	2011 Effect
single-class (OLS)		-0.1568***	0.0068***
	1st class	-0.0034	0.0002
	2nd class	-0.4415***	0.0058
5-class	3rd class	-0.0840***	0.0053**
	4th class	-0.1858***	0.0075**
	5th class	-0.1221***	0.0071***

* Significant at 10% level.

*** Significant at 1% level.

the fifth classes are not significant. Therefore, a higher level of income is not associated with a higher demand of water, i.e. water demand appears to be insensitive to changes in income.

We can also observe that the number of members per household has a positive effect on water consumption in both the single-class and 5-class model. Overall, the elasticities with respect to family size are quite heterogeneous among classes. However, the results show that, in every case, an increase in water use is less than proportional to an increase in the number of persons per household. This is consistent with other studies that have found economies of scale (Arbués and Villanúa, 2006).

As expected, the coefficient of the binary variable indicating home ownership is negative and significant in the single-class model. However, in the 5-class model, the ownership indicator is significantly negative for the second and the fourth classes, while it is positive and significant for Class 1, which is the class with such a low level of water consumption that we may assume that it includes consumers who belonging to this class do not inhabit the house and only consume water for cleaning and maintenance purposes. Therefore they do not have high incentives to invest in water-saving devices. For the other groups, this variable is not significant, indicating that owner occupiers in these classes do not differ significantly in terms of their water demand depending on whether they own their home or not. This result could be due to the high proportion of home ownership in Granada (as in the rest of Spain).

The water conservation *habits* adopted by households seem to have a negative and significant impact on water demand in four of the classes while being non-significant for the first class, i.e., the class with the lowest average water consumption. This finding suggests that most of the households in Granada are developing pro-saving water behaviors that allows them to reduce water demand.

Finally, the positive and significant coefficient of the *summer* indicator for the first, third, fourth and fifth classes implies that, ceteris paribus, higher levels of water consumption are registered during the summer months for households belonging to those classes. However, it is worth mentioning that there is a negative summer seasonal effect on water demand in the second class. This negative effect may be related to longer periods of holidays during summer months during which the home occupants are likely to avoid staying in the hot city of Granada if they can avoid it (by, for example, staying at a second home in the countryside or on the seaside). It is likely that those who can afford to be away from Granada for more than the usual four weeks of vacation to which Spanish workers are entitled will leave their city homes empty and use water elsewhere instead.

Following Deb and Trivedi (2002) and Ayyagari et al. (2013), we perform a descriptive analysis (see Table 8) of the different groups of consumers using a Fractional Multinomial Logit. We regress the estimated posterior probabilities for each of the five classes on a set of behavioral variables described in section 5. We obtained the following class profiles (marginal effects can be seen in Table 9):

- Class 1. The variable measuring the proportion of members over 65, the indicator of collaboration with an association for environmental defense, the indicator of knowledge of the price structure, the household size variable and the dummy variable for 2010 have negative and statistically significant coefficients (at the 1%, 10%,5% ,10%, and 10% level respectively). These results indicate that households with a higher proportion of members over 65, who collaborate with an association for environmental protection, with a better knowledge of the price structure and more members in the household are less likely to belong to Class 1. It is also remarkable that the probability of belonging to Class 1 decreases for observations from 2010. The average water demanded by consumers in this class is 1.8 m^3 every two months, i.e., falling within the first block in the price structure, as shown by Table 6.

- Class 2. The results for Class 2 show that, despite the positive and significant coefficients for *campaign* and *tariff*, which suggest that consumers in this class are well informed, do not have significant environmental concern, and are less likely to own water-efficient appliances. These consumers in Class 2 were the only ones for which summer consumption was lower than winter consumption. However, the probability of belonging to this class increases for summer observations from the year 2011 and from the year 2010. In 2010 water was cheaper in Granada, so belonging to this high-consumption class is more likely for observations from 2010. Interestingly, consumers in this class have a lower education level and, as can be seen in Table 6, their average water consumption is the highest. The analysis of the posterior probabilities confirms that these households contain a significantly higher proportion of retired persons, who are more likely to spend longer summer holidays away, and a bigger household size.

- Class 3. Households in this class are less likely to have a high proportion of members over 65 and a large household size. Moreover, they do not show

Table 8: Posterior probabilities regressions (reference category:class 5)

	Class 1	Class 2	Class 3	Class 4
constant	-1.9425***	-1.9317***	-0.8970***	-0.3984***
	(-11.2)	(-19.03)	(-12.9)	(-7.98)
education	-0.0952***	-0.0443**	-0.0032	-0.0127
	(-3.08)	(-2.46)	(-0.27)	(-1.47)
young16	0.2239	-0.1106	0.0574	-0.4115***
	(0.73)	(-0.67)	(0.45)	(-4.64)
old65	-0.3120***	0.1681***	-0.1332***	0.0336
	(-3.32)	(3.17)	(-3.81)	(1.27)
enviro	-0.2105*	-0.0423	-0.0822**	0.0208
	(-1.86)	(-0.73)	(-2.03)	(0.68)
campaign	0.1074	0.1940***	0.0150	-0.0097
	(1.62)	(4.74)	(0.56)	(-0.48)
tariff	-0.1181*	0.0890**	-0.0239	0.0598***
	(-1.67)	(2.18)	(-0.87)	(2.93)
electeff	-0.0479	-0.1324***	-0.0530***	0.0040
	(-1.05)	(-5.42)	(-3.08)	(0.32)
members	-0.0484	0.0506***	-0.0290*	0.0301***
	(-1.4)	(2.59)	(-1.91)	(2.91)
year2010	-0.1709**	0.1543***	-0.0660**	-0.0201
	(-2.07)	(3.06)	(-2.03)	(-0.82)
year2011	-0.0943	-0.0026	-0.0284	-0.0678**
	(-1.02)	(-0.04)	(-0.75)	(-2.4)
summer	-0.1448	-0.0954**	0.0011	-0.0489*
	(-1.62)	(-1.85)	(0.03)	(-1.94)
summer2011	-0.1275	0.2277***	-0.1122**	0.0795*
	(-0.84)	(2.86)	(-2.05)	(1.95)

Robust t-statistics are in parentheses

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

a great environmental concern and they have a worse knowledge of the price structure, according to the negative and significant coefficients of the *enviro* and *tariff* variables. Despite their non-positive attitudes towards the environment and low knowledge of the tariff structure, their average amount of water consumed in this class is relatively low. However, it increases significantly and substantially during the summer season, just as our intuition about the effect of old65, explained above for Class 2, would suggest. Most likely, this class captures young childless professionals in the earlier stages of their careers who do not own a vacation home outside the city. They likely have relatively cheaper homes in Granada too, with fewer water-efficient appliances, perhaps because of their limited access to credit. Additionally, the probability of belonging to Class 3 decreases for those observations from 2010.

- Class 4. The coefficient of *old65* is positive and significant in this class and the *young16* coefficient is negative and statistically significant, suggesting that consumers in this class may be families of diverse ages but mostly childless. They are more informed about the price struture and they have collaborated with an association for environmental defense; however, they are less likely to be aware of environmental campaigns. Households in this class are more likely to use water efficiency electrical appliances, as suggested by the positive and statistically significant coefficient of *electeff*. However, their average water consumption is 23.9 m^3 every two months, which can be considered relatively high. Furthermore, the probability of belonging to this class in 2011 decreases. Nevertheless, during the summer of 2011, the probability increased.

- Class 5. It represents the 44.77% of the sample. Consumers in this group seem to have a relatively high level of education. Regarding household composition, which could affect water-using routines, there is a relatively high proportion of members under 16, but the proportion of members over 65 is not significantly different from the average. In this class, consumers are less likely to be aware of environmental campaigns and the price structure. However, the own water efficient electrical appliances disproportionately more than those families in other classes. In general, the probability of belonging to Class 5 increases during the summer months as well as in 2011. The level of water consumption for this class is about 13 m^3 every two months.

Table 9: Marginal Effects of Fractional Multinomial Logit Regression

	Class 1	Class 2	Class 3	Class 4	Class 5
education	-0.0025***	-0.0024***	0.0010	-0.0007	0.0046**
young16	0.0102	0.0006	0.0255	-0.0893***	0.0530***
old65	-0.0091***	0.0126***	-0.0185***	0.0122***	0.0028
enviro	-0.0054*	-0.0020	-0.0097**	0.0108*	0.0063
campaign	0.0027	0.0127***	-0.0002	-0.0079*	-0.0073*
tariff	-0.0040**	0.0052**	-0.0060*	0.0128***	-0.0080*
electeff	-0.0009	-0.0083***	-0.0052***	0.0065***	0.0078***
members	-0.0017*	0.0031***	-0.0053***	0.0070***	-0.0032
year2010	-0.0047*	0.0121***	-0.0082**	-0.0033	0.0041
year2011	-0.0020	0.0018	-0.0001	-0.0122**	0.0124**
summer	-0.0035	-0.0050	0.0039	-0.0070	0.0116**
summer2011	-0.0042	0.0159***	-0.0187***	0.0174**	-0.0104

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

Next, in order to investigate whether the change in the price structure succeeded in reducing water demand, we analyse the evolution of water consumption during the period 2010-2011, which includes the time of change of the tariff structure.

Table 10 shows that indeed that the level of water demanded has changed considerably in 2011, average water consumption significantly decreased for the five groups of consumers. Following Olmstead et al. (2007), we have computed the average marginal prices, i. e., the price in the block of observed consumption, which show that the change in the price structure in 2011 benefitted consumers in class 1. Moreover, water demand is appreciably inelastic for Classes 3 and 5. Therefore, the decrease in water consumption may be partly caused by other factors such as the shape of the price structures or the expectations of the effect of the change in the structure on total bill.

Table 10: Evolution of average water consumed by classes

	2010		2011	
Classes	water consumed(m^3)	average MagP	water consumed (m^3)	average MagP
1	1.8517	1.0318	1.7329	0.9731
2	40.4048	2.2212	37.8938	2.6371
3	5.9580	1.0318	5.7738	1.2218
4	24.0492	1.8424	23.7297	2.1611
5	13.1731	1.3914	13.0819	1.5310

Means are significantly different at 1% level.

7. Conclusions and future extensions

The analysis in this paper provides strong evidence of heterogeneity in residential water demand in the city of Granada for the period 2009-2011. We have identified five different residential water consumer profiles in Granada for the period 2009-2011, rather than the common profile assumed by single equation approaches, and this estimation allowed us to observe five distinct prices responses.

Despite the fact that water demand is found to be inelastic for all the classes, the change in the price structure succeeded in reducing water demand. However, this change in the structure also caused water demand to become more inelastic for one of the classes, which represents 44.77% of the sample. Therefore, the implementation of pricing policies would be less effective in reducing water consumption for this group of consumers in the future.

Perhaps the more interesting conclusion is the answer to the question, given the demand function in a particular group of consumers, what should be the focus of the water demand management policy? Identifying different price elasticities allows regulators to predict more accurately the effect of different water conservation policies. In order to reduce water consumption, pricing and non-pricing policies such as education programs, water rationing, retrofit subsidies or public information campaigns can be jointly applied to the most price-responsive groups of consumers. However, non pricing policies would be preferred for non-price-sensitive consumers, as they may encourage consumers to become more price sensitives. Information about different groups of consumers may be very helpful to design a more efficient and equitative tariff.

Although we focused on price responses, it could be possible to extend the analysis to examine whether the decrease in water demand could be driven by the shape of the price structure. Another suggestion for further research is to extend the model in order to analyse whether households consuming at the kink points switched classes after the change in the price structure, via a Markov process.

Acknowledgements

The authors would like to thank financial support (grant: UNOV-11-BECDOC) given by the University of Oviedo and the Spanish Ministery of Economy and Competitiveness (ECO2009-08824).

Appendix

Selected questions from the survey used to construct a water habits index:

P.17. In general, do you have any of the following water conservation habits in the household?

a) Do you recycle water, for example, making use of the water while you wait for the shower to get hot?

b) Do you store drinking water in the refrigerator rather than letting the tap run every time you want a cool glass of water?

c) Do you defrost food in advance in order to avoid using running hot water to thaw meat or other frozen foods?

d) Do you fill the sink with water when washing dishes by hand?

e) Do you operate automatic dishwashers and washing machines only when they are fully loaded?

f) Do you slightly turn off the backflow valve to reduce the tap flow?

g) Do you use a rubbish bin in the toilet rather than flushing the toilet unnecessarily?

h) Do you avoid letting water run while brushing your teeth?

i) Do you take shorter showers?

j) Do you avoid washing the cars with drinking water?

References

Arbués, F., M. García-Valiñas, and R. Martinez-Espiñeira: 2003, 'Estimation of residential water demand: A state-of-the-art review'. *Journal of socio-economics* **32**, 81–102.

Arbués, F. and I. Villanúa: 2006, 'Potential for Pricing Policies in Water Resource Management: Estimation of Urban Residential Water Demand in Zaragoza, Spain'. *Urban studies* **43**(13), 2421–2442.

Ayyagari, P., P. Deb, J. Fletcher, W. Gallo, and J. Sindelar: 2013, 'Understanding heterogeneity in price elasticities in the demand for alcohol for older individuals'. *Health Economics* **22**(1), 89–105.

Barberán, R., I. Villanúa, and F. Arbués, F.: 2000, 'Water Price Impact On Residential Water Demand In Zaragoza City. A Dynamic Panel Data Approach'. ERSA conference papers ersa00p167, European Regional Science Association.

Beaumais, O., A. Briand, K. Millock, and C. Nauges: 2010, 'What are Households Willing to Pay for Better Tap Water Quality? A Cross-Country Valuation Study'. Université Paris 1 Panthéon-Sorbonne (Post-Print and Working Papers), HAL.

Billings, R. B.: 1982, 'Specification of Block Rate Price Variables in Demand Models'. *Land Economics* **58**(3), 386–394.

Boter, J., J. Rouwendal, and M. Wedel: 2005, 'Employing Travel Time to Compare the Value of Competing Cultural Organizations'. *Journal of Cultural Economics* **29**, 19–33.

Cameron, A. C. and P. K. Trivedi: 2005, *Microeconometrics: Methods and applications*. Cambridge University Press, New York.

Campbell, D., D. A. Hensher, and R. Scarpa: 2011, 'Non-attendance to attributes in environmental choice analysis: A latent class specification'. *Journal of Environmental Planning and Management* **54**(8), 1061–1076.

d' Uva, T. B.: 2006, 'Latent classmodels for utilisation of health care'. *Health Economics* **15**, 329–343.

Dalhuisen, J. M., R. Florax, H. D. Groot, and P. Nijkamp: 2003, 'Price and Income Elasticities of Residential Water Demand: A Meta-Analysis'. *Land Economics* **79**(2), 292–308.

Deb, P. and P. K. Trivedi: 2002, 'The structure of demand for health care: Latent class versus two-part models'. *Journal of Health Economics* **21**, 601–625.

Fernandez-Blanco, V., L. Orea, and J. Prieto-Rodriguez: 2009, 'Analyzing consumers heterogeneity and self-reported tastes: An approach consistent with the consumer's decision making process'. *Journal of Economic Psychology* **30**, 622–633.

Grafton, R. Q., M. B. Ward, H. To, and K. T.: 2011, 'Determinants of residential water consumption: Evidence and analysis from a 10-country household survey'. *Water Resources Research* **47**(W08537, doi:10.1029/2010WR009685).

Greene, W. and D. Hensher: 2013, 'Revealing additional dimensions of preference heterogeneity in a latent class mixed multinomial logit model'. *Applied Economics* **45**(14), 1897–1902.

Grisolía, J. M. and K. G. Willis: 2012, 'A latent class model of theatre demand'. *Journal of Cultural Economics* **36**, 113–139.

Hensher, D. A. and W. H. Greene: 2003, 'The Mixed Logit model: The state of practice'. *Transportation* **30**, 133–176.

Hess, S., M. Ben-Akiva, and J. Walker: 2011, 'Advantages of latent class over continuous mixture of Logit models'. *Working paper, University Press, Harrisburg.*

Hewitt, J. A. and W. M. Hanemann: 1995, 'A discrete/continuous choice approach to residential water demand under block rate pricing'. *Land Economics* **71**, 173–192.

Hyppolite, J. and P. Trivedi: 2012, 'Alternative approaches for econometric analysis of panel count data using dynamic latent class models (with application to doctor visits data)'. *Health Economics* **21**(1), 101–128.

Krause, K.: 2003, 'The Demand for Water: Consumer Response to Scarcity -'. *Journal of Regulatory Economics* **23**(2), 167–191.

Mansur, E. T. and S. M. Olmstead: 2012, 'The Value of Scarce Water: Measuring the Inefficiency of Municipal Regulations'. *Journal of Urban Economics* **71**, 332–346.

Martínez-Espiñeira, R. and C. Nauges: 2004, 'Is all domestic water consumption sensitive to price control?'. *Applied Economics* **36**(15), 1697–1703.

Nauges, C. and D. Whittington: 2010, 'Estimation of Water Demand in Developing Countries: An Overview'. *The World Bank Research Observer* **25**(2), 263–294.

Olmstead, S., M. W. Hanemann, and R. N. Stavins: 2007, 'Water demand under alternative price structures'. *Journal of Environmental Economics and Management* **54**, 181–198.

Olmstead, S. M.: 2009b, 'Reduced-Form Versus Structural Models of Water Demand Under Nonlinear Prices'. *Journal of Business and Economics Statistics* **27**(1), 84–94.

Papke, L. and J. M. Wooldridge: 1996, 'Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates'. *Journal of Applied Econometrics* **11**, 619–632.

Patunru, A. A., B. J. B., and S. Chattopadhyay: 2007, 'Who Cares about Environmental Stigmas and Does It Matter? A Latent Segmentation Analysis of Stated Preferences for Real Estate'. *American Journal of Agricultural Economics* **89**(3), 712–726.

Pint, E.: 1999, 'Household responses to increased water rates during the California drought'. *Land Economics* **75**, 246–266.

Renwick, M. and S. Archibald: 1998, 'Demand side management policies for residential water use: who bears the conservation burden?'. *Land Economics* **74**, 343–359.

Renwick, M. E. and R. D. Green: 2000, 'Do Residential Water Demand Side Management Policies Measure Up? An Analysis of Eight California Water Agencies'. *Journal of Environmental Economics and Management* **40**, 37–55.

Rinaudo, J. D., N. N., and M. Montginoul: 2012, 'Simulating the impact of pricing policies on residential water demand: a southern France case study'. *Water Resour Manage* **26**, 2057–2068.

Roibás, D., M. García-Valiñas, and A. Wall: 2007, 'Measuring welfare losses from interruption and pricing as responses to water shortages: an application to the case of Seville'. *Environmental & Resource Economics* **38**(2), 231–243.

Ruijs, A., A. Zimmermann, and A. M. v. d. Berg: 2008, 'Demand and distributional effects of water pricing policies'. *Ecological Economics* **66**(2-3), 506–516.

Russell, S. and K. Fielding: 2010, 'Water demand management research: A psychological perspective'. *Water Resources Research* **46**(W05302, doi:10.1029/2009WR008408).

Scarpa, R., M. Thiene, and T. Tempesta: 2007, 'Latent class count models of total visitation demand: days out hiking in the eastern Alps'. *Environmental and Resource Economics* **38**(4), 447–460.

Scarpa, R., K. G. Willis, and M. Acutt: 2005, 'Individual-specific welfare measures for public goods: A latent class approach to residential customers of Yorkshire Water'. *Econometrics Informing Natural Resource Management,* **14**, 316–337.

Shen, J.: 2010, 'Latent class model or mixed logit model? A comparison by transport mode choice data'. *Applied Economics* **41**, 2915–2924.

Shen, J., Y. Sakata, and Y. Hashimoto: 2006, 'A Comparison between Latent Class Model and Mixed Logit Model for Transport Mode Choice: Evidences from Two Datasets of Japan'. Discussion Papers in Economics and Business 06-05, Osaka University, Graduate School of Economics and Osaka School of International Public Policy (OSIPP).

Stern, P. C.: 2000, 'New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior.'. *Journal of Social Issues* **56**, 407–424.

The World Bank: 2012, 'Turn down the heat. Why a 4 C warmer world must be avoided'. Technical report, The World Bank.

UNDESA: 2009, 'World Population Prospects, The 2008 Revision- Executive Summary'. Technical report, UNDESA (United Nations Department of Economic and Social Affairs).

Worthington, A. C., H. Higgs, and M. Hoffmann: 2009, 'Residential water demand modeling in Queensland, Australia: a comparative panel data approach'. *Water Policy* **11**(4), 427–441.

Worthington, A. C. and M. Hoffman: 2008, 'An Empirical survey of Residential Water Demand Modelling'. *Journal of Economic Surveys* **22**(5), 842–871.