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Regional Differences in the Price Elasticity of Residential Water Demand in Spain

David Hoyos[1,2] · Alaitz Artabe[3]

Abstract This paper explores the influence of regional climate variability on the elasticity of price for residential water demand in Spain. The data comes from the Spanish Survey of Family Budget (INE 2012), a national based survey of household living conditions including more than 15,000 observations. The econometric analysis included other determinants of residential water demand in Spain such as income and household characteristics. In line with the broad literature, the demand for water in Spain is found to be inelastic, although price elasticity differs notably when accounting for different climatic regions in the territory. The results have noteworthy policy implications as water pricing is considered an efficient means of long term sustainable planning of water resources management. The results imply that policy makers may have reasons to explore differentiating the impacts of water efficiency measures by region.

Keywords Residential water demand · Water resources management · Water pricing · Price elasticity · Income elasticity · Econometric modelling

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1 Introduction

Water is a natural resource that fulfils vital needs for the right functioning of ecosystems and living beings. That is the main reason why water availability has been a major factor explaining human settlements and development. Being a valuable and scarce resource explains both its high economic and social value as well as why water management has become a main policy issue for decision-makers all over the world. This is especially the case for Spain, where historic attempts to better adjust an increasing demand with rising water scarcity has made water management to play a central role in the public policy debate (Arbués et al. 2004). The difficulties of water supply to meet rising demand have added pressure to the public debate on two sides: among users and uses of water; and among regions. Furthermore, climate change is predicted to significantly rise temperatures in Spain thus further increasing the pressure on water demand. According to the Intergovernmental Panel on Climate Change (IPCC), climate change is projected to reduce the availability of renewable surface water and groundwater resources significantly in Southern Europe by the end of the twenty-first century (Barros and Field 2015; Carvalho et al. 2015). As a consequence, it is expected higher competition for its use among ecosystems, agriculture, settlements, industry and energy production. In addition, climate change is expected to reduce raw water quality provoking higher risks to drinking water quality.

As the availability of water is expected to reduce in the near future, economic instruments for water management may have an important role to play in order to guarantee an efficient and sustainable use of the natural resource. As argued by García-Ruiz et al. (2011), more robust water management, pricing and recycling policies are required to ensure an adequate water supply and prevent tensions among different users. In addition, there are other factors expected to shift water demand, such as income level of the households, demographic changes, legislation developments such as the European Water Framework Directive (European Union 2000),[1] rainfall patterns or rising temperatures.

The economic analysis of water demand requires a good understanding of the response of consumers to price changes. Prices are an economic incentive that allows users to adapt efficiently to changes in the supply of water. So, from an economic efficiency perspective, water pricing may serve as a powerful tool for redesigning incentives and guiding demand to most valuable uses. In fact, there are multiple examples of how prices have been used as an effective tool for reducing excessive water consumption (EEA 2013): in Denmark, between 1993 and 2004 the real price of water rose by 54%, resulting in a 20% drop in water consumption from 155 l per day and person to 125. Similarly, a sharp rise in the price of water in Czech Republic reduced consumption by 40% up to 103 l per day and person.

Water management by means of economic instruments requires a sound analysis of the determinants of demand. More precisely, the econometric analysis of residential water demand is used to measure the sensibility of households' demand to variations in the levels of several explanatory variables, such as the price of water or different household characteristics. The appealing of studying the sensibility of the demand to variations in prices (i.e. the elasticity of demand) is due to the fact that efficient and sustainable price regimes may be based on the different sensibilities to price changes of different water users. Economic theory suggests that

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[1] The approval of the European Directive in 2000 established a paradigmatic shift in the public management of water resources, not only in regards to its main objective (i.e. improving the environmental quality of European waters) but in the use of economic analysis as one of the main pillars for its implementation (Union 2000; Kristensen et al. 2013; Tsakiris 2015).

the demand for a good or service depends on its price and that this relation is negative, i.e. the lower the price the higher the demand.

The literature on residential water demand is vast (for a review, see e.g. Dalhuisen et al. 2003; Schleich and Hillenbrand 2009; Grafton et al. 2011). Table 4 in Appendix 2 summarises key past findings in European countries. The type of data used is either household or community data, mainly in the form of panel data. The dependent variable is typically average water consumption, with price, income, other household characteristics such as size or age, climatic factors such as temperatures or rainfall levels as key explanatory variables. Most frequently log-log or semi-log functional forms of the demand equation are used, thus allowing parameters to be directly interpreted as elasticities. Key findings are presented in terms of (1) price elasticity; (2) income-elasticity; and (3) non-price factors. In general, residential water consumption is found to respond inelastically to price changes, with estimates ranging between very low levels (close to zero) up to −0.8. These results are also in line with the results found in two meta-analysis: an average price elasticity of demand of −0.51 (Espey et al. 1997) and −0.41 (Dalhuisen et al. 2003). These low estimates of price elasticity are usually explained by the relatively low share of water costs in total house expenditures. Empirical evidence regarding income elasticity shows that water demand is rather inelastic in terms of income changes with typical estimates lying around 0.5, confirming that water is a normal good. Finally, regarding non-price factors, most authors find household size and higher temperatures to be positively related to consumption while household age and higher summer rainfall levels to be negatively related to it. None of the studies reviewed, however, has attempted to explain heterogeneous price elasticities of residential water demand due to different climatic regimes.

This paper explores the influence of regional climate variability on the elasticity of price for residential water demand in Spain. The main contribution of the paper is to provide with region-specific price elasticities under different climatic and socioeconomic conditions in the territory. Based on a sample of over 15,000 observations obtained from the Spanish Survey of Family Budget (INE 2012), the econometric analysis allows us to control for different determinants of residential water demand in Spain, including price, income, climatic conditions and household characteristics. We find that the demand for water in Spain is inelastic (−0.29) and that it differs notably when accounting for different climatic regions in the country (i.e. Northern, Central, Southern, Eastern and Canarian Region). These results are policy relevant as water pricing is considered an efficient means of long term sustainable planning of water resources management.

The rest of the paper is structured as follows. Section 2 reports the data used; Section 3 provides with the methodology applied; Section 4 synthesises the main results; and Section 5 discusses the main findings and provides with some final remarks.

2 Data

We use individual household data of water consumption to estimate a residential water demand model for Spain. Aggregate data is often used to estimate water demand models due to the difficulty of obtaining individual data. However, individual household data allows us to capture household level effects, so that more detailed information on consumption patterns of Spanish families may be extracted. We obtain the data from the Spanish Survey of Family Budget (INE 2012), where households indicate their expense and consumption levels in different goods and services during 2012. The final sample includes 15,557 households. The sample is found to be representative of the population in terms of household size, income level and average water consumption and price.

We model WATER DEMAND in terms of water price and some household characteristics, such as, income level, number of members and the region where the house is located. The variable QWATER measures the household "tap water" consumption during 2012. We expect two of the most important determinants of water demand to be water price and family income. We also expect that PRICE increase results in a reduction of water consumption, as well as, an increase in income results in an increase on water consumption. Usually, these effects are measured by price and income elasticities. Price elasticity tends to be negative when the good is normal (Nauges and Thomas 2000; Martínez-Espiñeira and Nauges 2004; Arbues and Villanua 2006). In most cases, water demand is estimated as inelastic. This happens because price elasticity tends to be inelastic in short term, due to the fact that individuals need time to react to price changes (Nauges and Thomas 2000; Martínez-Espiñeira 2007; Musolesi and Nosvelli 2007). Moreover, water demand response to price changes may depend on its use: small response to price changes (low price elasticity) when it is used for necessities, like drink and cook, or big response to price changes when it is used for non-necessities, such as, irrigate the garden or clean the car. Individuals' knowledge about tariff structure is often small so their responsiveness to price changes is influenced by their lack of information about water prices (Gaudin 2006; Frondel and Messner 2008; Schleich and Hillenbrand 2009).

There is great controversy about the price of water that has to be taken into account when we model water demand. When the block rates tariffs are used, some studies employed marginal prices (e.g. Martínez-Espiñeira 2007; Martins and Fortunato 2007; Polycarpou and Zachariadis 2012). Although those individuals who perfectly know the tariff structure would react to marginal prices, the majority of the individuals do not know the price structure, thus they do not react to these changes. Households usually only identify the average price that appears in the bill and this is the price of water used in most applications (e.g. Arbues and Villanua 2006; Musolesi and Nosvelli 2007; Pérez-Urdiales et al. 2014). In this paper, we only consider average prices (i.e. the ratio between total expense in water and total water consumption) given the limitations of the data available.

We use the total net income as the INCOME level of the household. It is considered that the income elasticity is positive when the good is normal, so that the higher the income level, the higher the water demand. It is also expected that the demand of basic commodities have a lower response to income changes (i.e. lower income-elasticity), than the demand of luxury goods. The effect of income on water demand may not be constant for all income levels. Therefore, some studies also introduce a quadratic term of income in the demand model (e.g. Schleich and Hillenbrand 2009).

It seems reasonable to assume that the higher the number of household members, the higher the household water demand. Variable NUMEMBERS reflects the number of individuals of the house. Moreover, assuming that older people consume more water is consistent with previous studies (Lyman 1992; Schleich and Hillenbrand 2009). We control for this effect by introducing the dummy variable DEPCHILD that identifies the families with members younger than 16. Single family houses' water demand tends to be higher than no-single family house, due to outdoor usage of water, such as, gardening and pools (Nieswiadomy and Molina 1989; Dandy et al. 1997). SHOUSE indicates whether a house is a single-family house or not. Customs and educational level can also be determinant on the level of water demand. Customs usually have to do with the nationality of the family. Moreover, it can be expected that the level of education influences on the awareness of responsible use of water.

Finally, climatic factors such as differences in the precipitation level (Billings and Agthe 1980; Billings 1982; Agthe et al. 1986) and temperatures (Billings 1987; Griffin and Chang 1990) are expected to be one of the major drivers of water consumption in Spain. The average

temperature in Southern regions is higher than in Northern and Central regions, increasing the level of water consumption in these areas. However, the precipitation level is lower in Southern regions, and so the pressure on water uses is higher. For example, the average temperatures during the period 1980–2010 in Bilbao and Seville were 14.7 and 19.2 respectively, while the average precipitation level during this period was 1134 and 539 respectively (AEMET 2015). We hypothesise that climatic differences may also explain regional differences in the price elasticity of residential water demand in Spain.

To summarise, water demand, measured as household "tap water" consumption, is usually modelled in terms of average price of water, climatic factors and household characteristics. In addition, dummy indicators for regions will be introduced in the model to control for regional effects.

3 Econometric Models

The first step in specifying an econometric model is choosing the appropriate functional form. The linear functional form was initially used due to its simplicity when estimating and interpreting the function (Moncur 1987; Schneider and Whitlatch 1991). However, it has been criticised because it assumes that the effects that price and income have on demand are constant. Moreover, the linearity assumption implies that there is a maximum price level for water consumption. In other words, contrary to the idea that water is essential good, it implies that above the maximum price level individuals' water consumption is zero.

Alternatively, the logarithmic functional form (i.e. log-log model) has gained popularity in recent years. This specification provides estimates of elasticities of demand, which are assumed constant over the entire domain of the variables. In order to avoid this inflexibility, some studies introduce the squared term of variables. The semi-logarithmic functional form is a third specification option for water demand. This functional form allows us to have more flexibility on the specification and interpretation of the model.[2] In this paper, we consider this third functional form.

$$
\begin{aligned}
ln(\text{qwater}) = {} & \beta_0 + \beta_1 ln(\text{price}) + \beta_2 ln(\text{income}) + \beta_3 [ln(\text{income})]^2 \\
& + \beta_4 \text{NuMember} + \beta_5 \text{qMinWater} + \beta_6 \text{DepChild} \\
& + \beta_7 \text{SHouse} + \beta_8 \text{SecEduc} + \beta_9 \text{UnivEduc} \\
& + \beta_{10} \text{PostUnivEduc} + + \beta_{11} \text{EUCountry} \\
& + \beta_{12} \text{EuroCountry} + \beta_{13} \text{WCountry} + \beta_{14} \text{NorthSpain} \\
& + \beta_{15} \text{WestSpain} + \beta_{17} \text{SouthSpain} \\
& + \beta_{18} \text{CanarianSpain} + \beta_{19} \text{Temp} + \beta_{20} \text{Prec} + u
\end{aligned}
\tag{1}
$$

As shown in the equation above, water demand is introduced in the model in natural logarithms, as well as price and income. This specification allows us to measure the proportional sensitivity of water demand to price and income changes (i.e. price and income elasticities). In order to avoid the restriction of constant proportional response of water demand to proportional income changes, we introduce the squared term of the natural logarithms of income. The expected income elasticity of demand will not be further constant, $\beta_2 + 2\beta_3$

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[2] There is a growing theoretical literature suggesting that income elasticity is unlikely to be constant (Barbier et al. 2016). As suggested by an anonymous reviewer, other non-linear more flexible relationships, such as Box-Cox transformation of dependent and explanatory variables, were investigated. However, we found a non-significant lambda parameter suggesting that the semi-logarithmic functional form fits the data best in this particular setting.

ln (*income*), as it will depend on the income level. The rest of the variables are mainly dummy or discrete variables (excepting *qMinWater, Temp* and *Prec*), so they take only discrete values. In this context, it is not appropriate to introduce them in logarithms. For a description of all the explanatory variables in the model, the reader may refer to Table 3 in Appendix 1.

A consistent estimation by Ordinary Least Squares (OLS) requires uncorrelated explanatory variables and the error term. However, not only water demand is determined by prices, but prices are also determined by quantity demanded. Then, unless price is totally inelastic, we may have an endogeneity problem and, as a consequence, OLS estimation would provide with biased and inconsistent estimates. In this context, we can use Instrumental Variables (IV) estimation procedure, which reports consistent estimated under endogeneity. Nevertheless, since individuals need time to adjust to new prices, there may not be an endogeneity problem between quantity demanded and prices at the same year. Furthermore, if an endogeneity problem does not exist, both OLS and IV are consistent, although OLS procedure provides with more efficient estimation.

Accordingly, we estimate the demand function by OLS and IV.[3] To test whether prices are uncorrelated with errors, we perform Wooldridge's (1995) endogeneity test. IV estimation requires instruments, which must be correlated with prices and uncorrelated with the error in the demand function, for the endogenous variable. In addition to the explanatory variables included in the OLS estimation, we introduce two instruments: (1) a variable that identifies whether the household is placed in a city with more than 5000 inhabitants (*LARGESIZE*)[4]; and (2) a variable that identifies the houses with hot water (*HOTWATER*). Both instruments are expected to be correlated with the price level and uncorrelated with the error term and, thus, satisfying the necessary conditions for instruments to provide with consistent estimations by IV. In order to test these conditions, we need to test for overidentification. Wooldridge's (1995) robust score test is performed for this purpose.[5]

4 Results

Table 1 shows OLS and IV estimation of the econometric model specified in Eq. (1). Together with the parameter estimates of the regression, the table provides with sample size (N), goodness of fit (R2) and the statistics for endogeneity and overidentification tests. First of all, we will focus on the analysis of the instruments used in the first step of the IV estimation procedure. The 0.98 ($p = 0.32$) value obtained in the overidentification test allows us to conclude that the two instruments used in the IV estimation satisfy the necessary exogeneity condition for obtaining consistent estimations. Moreover, the parameter estimates for the instruments in the first step exhibit the expected positive signs.

Once the validity of the instruments is tested, we focus on the comparison between OLS and IV. The exogeneity of variables in Eq. (1) is necessary for OLS to be consistent. However, Wooldridge's (1995) endogeneity test allows us to conclude that price is an endogenous

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[3] White's (1980) test is used to test the presence of heteroscedasticity in the error term and, under the null hypothesis of homoscedasticity, the test value is Chi2 (181) = 679.95 (*p* value <0.001). Therefore, we reject the null hypothesis and display robust standard errors.
[4] Population indicators are often used in the literature to instrumentalise prices. Schleich and Hillenbrand (2009) use natural logarithm of population and population density as instruments.
[5] The usually used Sargan (1958) and Basmann (1960) overidentification tests are not robust under heteroscedasticity since they assume that the errors are independent and identically distributed.

variable and so OLS estimation provides with inconsistent estimates (please, also note the different price elasticity estimates provided by OLS and IV). Thus, we focus on the analysis of the IV estimation.

As shown is Table 1, water demand is found to be price inelastic. When price increases by 1%, the quantity demanded decreases by 0.29% (i.e. the percentage change in quantity demanded is smaller than that in price). This result was expected due to the fact that water is a necessary good. Water is mainly used for activities that cannot be substituted and only a low percentage of this used is replaceable, so we are likely to find that changes in water prices may have a relatively small effect on water demand. The estimate for price elasticity is in line with the results found by Martínez-Espiñeira (2003) for Spain and they lie near the average elasticities found in the meta-analyses conducted by Espey et al. (1997) and Dalhuisen et al. (2003). These estimates are also in line with those found in similar studies conducted in France (Nauges and Thomas 2000; Nauges and Thomas 2003), Italy (Musolesi and Nosvelli 2007), Portugal (Martins and Fortunato 2007), Germany (Schleich and Hillenbrand 2009) and Cyprus (Polycarpou and Zachariadis 2012).

Table 1 Estimations of the Water Demand Function

	OLS		IV	
	est.	St. Error	est.	St. error
log(price)	−0.539 ***	0.013	−0.290 ***	0.054
log(income)	0.344	0.267	0.728 **	0.339
[log(income)]2	−0.017	0.018	−0.044 *	0.023
NuMember	0.090 ***	0.004	0.090 ***	0.005
qMinWater	2.630E − 05 **	0.000	0.003	0.003
DepChild	−0.039 ***	0.011	−0.041 ***	0.013
SHouse	0.021 **	0.010	0.071 ***	0.014
SecEduc	0.043 ***	0.012	0.034 **	0.016
UnivEduc	0.011	0.012	0.006	0.015
PostUnivEduc	0.035	0.049	0.017	0.048
EUCountry	0.093 ***	0.033	0.034	0.033
EuroCountry	0.097	0.084	0.155	0.096
Wcountry	0.108 ***	0.024	0.112 ***	0.028
NorthSpain	−0.057 ***	0.015	0.031	0.026
WestSpain	−0.069 ***	0.025	0.036	0.036
SouthSpain	−0.065 ***	0.024	0.038	0.037
CanarianSpain	−0.082 ***	0.028	−0.012	0.033
Temp	0.090 ***	0.005	0.060 ***	0.009
Prec	0.000	0.000	−0.001 ***	0.000
cons	1.496	0.990	0.520	1.265
R2	0.256		0.228	
Endogeneity test	Robust regression F (1,10,030) = 28.50 ($p < 0.001$)			
Overidentification test	Score chi2 (1) = 0.98 ($p = 0.32$)			

One, two and three asterisks correspond to 10, 5 and 1% significance levels

The income elasticity of water demand is found to be significant and inelastic (mean of individual-specific elasticities of 0.08),[6] so that a change on income level has a relatively small positive effect on water demand. The reason of this small effect may be found in the fact that water is an essential good with low substitutability (Roseta-Palma et al. 2013). This finding coincides with the values generally found in the literature, where income elasticity is usually found to be positive and significant (Ruijs et al. 2008; Schleich and Hillenbrand 2009; Roseta-Palma et al. 2013).

As expected, the parameter estimate for the variable that measures the number of members of family is positive and statistically significant, meaning that as the number of members of the household increases, water demand also increases. More specifically, an additional member in a household increases overall household's demand by 9%. Our parameter estimate for the variable that identifies families with children younger than 16 is negative meaning that, controlling for all the other variables, families with young children's demand for water decreases by 4.1%. This result is similar to other findings in the literature that conclude that as people get older, their level of water consumption increases (Martínez-Espiñeira 2002; Martins and Fortunato 2007; Schleich and Hillenbrand 2009). The usual interpretation of this result is that older people tend to use more water for washing and hygiene than young people. Moreover, retired people tend to spend more time at home and their use of water for gardening and home cleaning tends to be higher (Lyman 1992).

Single family house parameter estimate indicates that the demand of households that live in single-family houses is 7.1% higher. This result suggests that single-family houses are often bigger and have gardens and so they consume more water in cleaning and gardening. In regards to the level of education, we find that water demand is 3.4% higher if the main breadwinner has secondary education level. Origin significantly affects water demand to families whose main breadwinner was born outside Europe, increasing their water demand with respect to families whose origin is Spain or the rest of Europe.

Finally, climatic conditions are found to have a significant impact on water demand. On the one hand, we find that a 1 degree Celsius increase in average temperatures increases by 7.5% the demand for residential water. On the other hand, higher precipitation level in summer decreases the demand for residential water. Both these effects are expected and are in line with those generally found in the literature (Martínez-Espiñeira 2007; Schleich and Hillenbrand 2009; Grafton et al. 2011; Polycarpou and Zachariadis 2012). In fact, quite interestingly, region-specific dummy variables become non-significant when temperature and precipitation levels are included in the model, which may suggest that climatic conditions explain to a great extent the existence of regional differences in the demand for residential water in Spain.[7]

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[6] The income elasticity is calculated computing the mean of the individual-specific elasticities using household income level.

[7] In a previous model excluding climatic conditions we found statistically significant differences in water demand between regions in Spain: compared with the Central region, warmer regions (i.e. Western, Southern and Canary Islands) were found to have statistically significant higher water demand and colder regions (Northern) lower.

5 Discussion

In this section, we will deepen into the analysis of the elasticity of demand for residential water in Spain. The climate of Spain varies notably across the country so, by dividing the territory into five climatic regions that are expected to have different sensibilities to water price variations, we will explore the determinants of residential water demand at the regional level.

According to geographical situation and the orography, five climatic zones can be distinguished in Spain. First, the Northern Region (Galicia, Asturias, Cantabria and Basque Country), has an oceanic climate, mainly characterised by relatively mild winters and warm summers. Both climate and landscape in this region are determined by the Atlantic Ocean winds. The rainfall is generally abundant, exceeding 1000 mm and is fairly evenly spread out over the year. Secondly, the Central Region of Spain is characterised by a Continentalised Mediterranean climate. This climate is predominant in Spain, as it covers the vast Central *Meseta* of the interior. Although it rarely rains during the summer, there is often heavy rainfall in spring and autumn. The annual rainfall exceeds 500 mm. Thirdly, the Eastern Region of Spain has a standard Mediterranean climate, characterised by dry and warm summers and cool to mild and wet winters. As in the Central Region, rains are rare during the summer and there is heavy rainfall in spring and autumn. Fourthly, the Southern Region of Spain is mainly characterised by having a semiarid climate. Although it shares with the Mediterranean climate very hot temperatures during the summer, the drought usually extends into the autumn. The rainfall is generally scarce, at about 300 mm. Finally, the Canarian Region (i.e. Canary Islands) is characterised by having a subtropical climate in terms of temperature, this being mild and stable throughout the year. In terms of precipitation, it is generally semiarid in the Eastern islands, although Western islands receive more rainfall.

This climatic distinction allows us also to disentangle regional differences in the price elasticity of the demand for water. In the previous section, we found that water demand was, on average, price inelastic (i.e. -0.29) and that income elasticity was statistically significant and inelastic (i.e. 0.08). These results change notably when we distinguished the analysis for climatic regions.

Table 2 provides with the main results of the econometric models conducted for each region (details can be found in tables A3.1-A3.5 in Online Resources 1).[8] Water demand differs in many aspects when distinguishing climatic regions: while average water consumption in Spain stays around 120 m3, Northern and Central regions exhibit lower average consumption (107.83 and 105.37 m3 respectively) and Eastern, Southern and Canarian regions exhibit higher average consumption. The price faced by consumers differs also along regions, highest at Eastern region (1.62 €) and lowest at Northern region (1.09 €).

The estimate for the price elasticity of the demand for water in the Northern Region is the highest for all regions (−1.32) suggesting that water demand in this

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[8] Variable HOTWATER is not a good instrument for PRICE in the regression of the East Region according to Wooldridge's (1995) robust score test. As a consequence, RENTALPERICEm2 is used as a second instrument in the East Region. RENTALPERICEm2 is the mean rent price for m2 of a house with the same characteristics (province, size, residential area, type of building).

Table 2 Price elasticity of demand by regions

	Spain (average)	North	Central	East	South	Canarian
Average quantity (m3)	118.29	107.83	105.37	124.97	145.90	132.89
Average Price (€/m3)	1.37	1.09	1.44	1.62	1.46	1.54
Price elasticity	−0.29	−1.32	−0.22	−0.41	n.s.	−0.39
Income elasticity (mean income)	0.08	n.s.	n.s.	n.s.	0.10	n.s.

n.s. = statistically not significant

region is price-elastic: a 1% increase in price decreases the demand for residential water by 1.32%. The reason for this deviation from the Spanish mean price elasticity may be found in its relatively higher supply, given that the availability of fresh water is higher, consumers may be more sensitive to small changes in price. Number of members of the household, demand for mineral water and having children have a significant and similar to Spain impact on water demand (see table A3.1 in Online Resources 1).

When looking at the Central region, the picture changes dramatically, with a significant estimate of −0.22 for the price elasticity of the demand for water (i.e. price-inelastic). This estimate suggests that the demand for water in this region is considered a necessary good. Low elasticity of water demand has been usually attributed to the absence of substitute goods and the relatively small proportion that water represents in household's expenses (Arbués et al. 2004). In this case, number of members of the household, having children and the education level and origin of household's breadwinner have a significant and similar to Spain impact on water demand (see table A3.2 in Online Resources 1).

The elasticity of price in the Eastern region is estimated at −0.41, slightly higher than the Spanish average and higher than the also Mediterranean climate of the Central region. Number of members of the household, demand for mineral water, living in a single family house and the education level and origin of household's breadwinner have a significant impact on water demand (see table A3.3 in Online Resources 1).

Sothern region, on the other hand, shows a non-significant price elasticity of demand for water, suggesting that, as in Central Region, the demand is totally price-inelastic. However, we find that the South is the only region with a significant elasticity of income, estimated at 0.10, i.e. a 1% increase in the income level is associated with a 0.10% increase in water demand. This finding is in line with the results usually found in the literature (Ruijs et al. 2008; Schleich and Hillenbrand 2009). Number of members of the household and living in a single family house have a significant and slightly higher that Spain impact on water demand. This can be explained by the fact that single family houses in dry regions would be expected to consume more water. As with previous regions, origin of household's breadwinner has a significant and similar to Spain impact on water demand (see table A3.4 in Online Resources 1).

Finally, in a totally different geographical location and with a subtropical climate, Canarian region's price elasticity is estimated at −0.39, similar to the Eastern region and slightly higher than the Spanish average. Number of members of the household, demand for mineral water, living in a single family house and the education level and origin of household's breadwinner have a significant impact on water demand (see table A3.5 in Online Resources 1).

6 Conclusions

This paper has analysed residential water demand in Spain, with a specific focus on regional differences based on different climatic areas. The applied model was used to econometrically analyse the impact of different socioeconomic and environmental determinants on Spanish households' demand for water, based on cross-sectional data obtained from the Spanish Survey on Family Budget for over 15,000 families in 2012. The functional form for water demand was semi-logarithmic, thus allowing more flexibility on the specification and interpretation of the model. Endogeneity problem of price was specifically treated by IV. The demand for water in Spain was found to be inelastic (although not insensitive) to price variations, i.e. price elasticity was less than unity (−0.29) but significantly different from zero. Our estimate of price elasticity lies in a similar range of those found for other European countries.

However, when accounting for regional climatic differences, we find heterogeneous price elasticities. The demand for water is found to be elastic in the Northern region (−1.32), where the availability of water is higher due to their oceanic climate, and more inelastic in Central and Southern regions, with more limited availability of water due to their Mediterranean drier climate. In between them, Eastern and Canarian regions are found to be, in line with the Spanish average, price inelastic (−0.41 and −0.39, respectively). Income differences were analysed by allowing income elasticity to vary for different income levels. In line with the literature, we find that income elasticity of water demand is significant and inelastic (mean elasticity of 0.08).

Also in line with similar studies conducted in other countries, our econometric results suggest that bigger households and living in single houses would increase overall households' water demand. On the contrary, families with children and a higher demand for mineral water results in a decrease on the demand for water. Origin of the household's main breadwinner also has a significant effect on water demand. Climatic conditions (temperature and precipitation level) are also found to have a significant impact on water demand. Furthermore, climatic conditions explain, to a great extent, the regional differences found when modelling the demand for residential water, with regions with lower average temperature and higher precipitation level are found to have lower water consumption, while regions with higher average temperatures and lower precipitation level are found to have higher water consumption.

These results have noteworthy policy implications as water pricing is considered an efficient means of long term sustainable planning of water resources management. The results imply that policy makers in Spain may have strong reasons to explore differentiating the impacts of water efficiency measures by region.

Appendix 1: Variables

Table 3 Descriptive statistics of the variables used

Variable	Description	Obs.	Mean	Stand. Dev.	min	max
qwater	water consumption quantity	15,557	118.295	61.368	32.400	317.200
price	water price	15,557	1.367	0.523	0.548	2.599
income	income	15,557	1857.737	873.842	585.000	4230.000
NuMember	number of members of family	15,557	2.772	1.212	1.000	12.000
qMinWater	mineral water consumption quantity	15,557	214.791	408.713	0	7535.092
DepChild	1 if living children younger than 16, 0 otherwise	15,557	0.209	0.407	0	1
SHouse	1 if it is a single family house, 0 otherwise	15,557	0.324	0.468	0	1
BasicEduc	1 if basic education is the highest study level of the main breadwinner, 0 otherwise	15,557	0.546	0.498	0	1
SecEduc	1 if Secondary education is the highest study level of the main breadwinner, 0 otherwise	15,557	0.182	0.386	0	1
UnivEduc	1 if University Studies is the highest education level of the main breadwinner, 0 otherwise	15,557	0.258	0.437	0	1
PostUnivEduc	1 if the main breadwinner has Post-University studies, 0 otherwise	15,557	0.013	0.114	0	1
SPCountry	1 if the main breadwinner was born in Spain, 0 otherwise	15,557	0.925	0.263	0	1
EUCountry	1 if the main breadwinner was born in a Country of the European Union (EU), 0 otherwise	15,557	0.022	0.147	0	1
EuroCountry	1 if the main breadwinner was born in a Country of Europe that is not a member of EU, 0 otherwise.	15,557	0.003	0.055	0	1
Wcountry	1 if the main breadwinner was born in a Country that is not in Europe, 0 otherwise.	15,557	0.049	0.218	0	1
NorthSpain		15,557	0.343	0.475	0	1

Table 3 (continued)

Variable	Description	Obs.	Mean	Stand. Dev.	min	max
	1 if the house is in the North Region of Spain, 0 otherwise.					
CentralSpain	1 if the house is in the Central Region of Spain, 0 otherwise.	15,557	0.232	0.422	0	1
WestSpain	1 if the house is in the West Region of Spain, 0 otherwise.	15,557	0.214	0.410	0	1
SouthSpain	1 if the house is in the West Region of Spain, 0 otherwise.	15,557	0.161	0.368	0	1
CanarianSpain	1 if the house is in the Canarian Islands, 0 otherwise.	15,557	0.049	0.215	0	1
Temp	Annual mean temperature (in degrees Celsius) in the Autonomous Community of residence	15,557	15.767	2.162	11.750	19.300
Prec	Average summer precipitation (in mm)	15,557	33.685	22.615	0.020	85.930
Instruments						
LargeSize	1 if the city has more than 50,000 inhabitants, 0 otherwise.	15,557	0.512	0.499	0	1
HotWater	1 if the house has hot water, 0 otherwise	15,557	0.999	0.031	0	1

Appendix 2: Literature review

Table 4 Literature review on residential water demand in Europe

Author(s)	Data type	Dependent variable(s)	Key explanatory variables	Functional form	Estimation technique	Price elasticity (absolute value)	Income elasticity	Other findings
(Höglund 1999). Sweden.	1980–1992; panel; community level	Per capita average consumption	Marginal price, fixed price, average price, income; household size	Log-log	OLS; GLS; 2SLS	0.08–0.12 (marginal); 0.20–0.26 (average)	0.07–0.13	Economies of scale in water consumption
(Nauges and Thomas 2000). France.	1988–1993; panel; community level	Annual water consumption per average user	Average price / marginal price, income, share of population over 60, population density, summer rainfall, share of single housing units, shares of houses built before 1949 and after 1982	Log-log	OLS; GLS	0.22–0.24	0.09–0.49	Lower consumption for communities with high share of houses built after '82, and with high share of singlehousing units; water use tends to increase with population age; rainfall not statistically significant
(Martinez-Espiñeira 2002). Spain.	1993–1999; panel; community-level	Monthly consumption per average account	Marginal-price, fixed price; billing frequency; income (proxy), household size, shares of population over 64 and under 19, temperature, rainfall	Linear	FE and BG	0.12–0.17	n.a.	Price elasticity higher in summer; climate variables are significant but of low magnitude
(Martinez-Espiñeira 2003). Spain.	1993–1999; panel; community-level	Proportion of consumers in various use-blocks; monthly consumption per average account	Marginal-price, fixed price; income (proxy), shares of population over 64 and under 19, temperature, rainfall	Linear	Logit; IV OLS; GLS	0.37–0.67	n.a.	Share of users falling in higher use-blocks and water consumption increases with income, with share of population under 19 and with temperature
(Nauges and Thomas 2003). France.	1988–1993; panel; community level	Annual water consumption per average user	Average price, one period lagged consumption, income	Log-log	GMM	0.26 (short-run); 0.40 (long-run)	0.51	Dynamic water consumption model can be derived from a

Table 4 (continued)

Author(s)	Data type	Dependent variable(s)	Key explanatory variables	Functional form	Estimation technique	Price elasticity (absolute value)	Income elasticity	Other findings
								municipality's dynamic objective function
(Martinez-Espiñeira and Nauges 2004). Seville, Spain.	1991–1999; time series; community level	Average per capita monthly water consumption	Marginal price, income (proxy), normal rainfall, maximum temperature, hours of supply restrictions	Stone–Geary	GLS	0.1	0.1	Almost half the consumption is used for basic needs and does not respond to price changes; rainfall is statistically significant
(Arbués et al. 2004). Zaragoza, Spain.	1996–1998; household level	Daily consumption per household	Average price (lagged by two measuring periods), income (proxy), household size	Semi-log	GMM	0.029–0.058	0.074–0.208	Economies of scale in water use
(Garcia and Reynaud 2004). Bordeaux area, France.	1995–1998; panel; community level	Annual water consumption per customer	Marginal price, average taxable income per household, household size, proportion of housing not equipped with a bath or a toilet, proportion of houses built after 1982, proportion of industrial users; summer rainfall	Log-log	GMM	0.25	not significant	People in newer houses use more water; summer rainfall not statistically significant
(García-valiñas 2005). Seville, Spain.	1991–2000; panel; household level	Quarterly consumption per household	One period lagged average price; income (proxy), household size	Linear	GMM	0.46–0.55	0.58	Tariffs based on seasonal demands tend to improve welfare for all user groups; distributional goals achievable at low welfare costs; economies of scale in water use
(Arbués and Villanua 2006). Zaragoza, Spain.	1996–1998; panel; household level	Daily consumption per household	Average price (lagged by two measuring periods), income (proxy), household	Linear	Two-step GLS	0.08	0.79	Average price and linear functional form are most appropriate specifications;

Table 4 (continued)

Author(s)	Data type	Dependent variable(s)	Key explanatory variables	Functional form	Estimation technique	Price elasticity (absolute value)	Income elasticity	Other findings
								economies of scale in water use; higher temperature means lower water use
(Mazzanti and Montini 2006). Italy.	1998–2001; community level	Per capita annual average consumption	Price (central block tariff), income, household size, shares of population over 65 and under 19, population density, altitude	Log-log	FE	0.99–1.33	0.40–0.71	Lower water consumption in higher altitudes; socioeconomic factors not statistically significant
(Martinez-Espiñeira 2007). Seville, Spain.	1991–1999; time series; community level	Average per capita monthly water consumption	Marginal price, income (proxy), normal rainfall, average daily maximum temperature, hours of supply restrictions	Linear	OLS	0.10 (short-run); 0.50 (long-run)	n.a.	Consumption and series of other determinants are nonstationary, but cointegrated; temperature is statistically significant, rainfall not
(Musolesi and Nosvelli 2007). Italy.	1998–2001; panel; community level	Average annual consumption per household	Average price, one period lagged consumption, income, share of population over 65	Log-log	FE GMM	0.27 (short-run); 0.47 (long-run)	0.18	Higher share of people over 65 leads to lower household consumption
(Martins and Fortunato 2007). Portugal.	1998–2003; panel; community level	Monthly average consumption per residential account	Marginal price, income (proxy), household size, share of population over 64, normal maximum monthly temperature, rainfall	Linear	RE GLS	0.56	n.a.	Higher share of people over 65 leads to lower household consumption; higher temperatures raise consumption; rainfall not significant
(Schleich and Hillenbrand 2009). Germany.	2003; Cross-sectional; community level	Average daily consumption per community	Marginal price, income, household size, average age, wells, housing patterns rainfall and temperatures	Semi-log; log-log	OLS, 2SLS	0.24 (average)	0.355	Household size and age leads to higher consumption. Rainfall patterns affect water consumption while temperature has no impact

Table 4 (continued)

Author(s)	Data type	Dependent variable(s)	Key explanatory variables	Functional form	Estimation technique	Price elasticity (absolute value)	Income elasticity	Other findings
(Polycarpou and Zachariadis 2012). Cyprus.	2000–2009; panel; household level	Quarterly consumption per household	Marginal price, average price, income; rainfall, temperatures	Log-log	OLS, 2SLS	0.25 (average); 0.45 (marginal)	0.53	Higher temperatures and rainfall levels increase consumption. Water saving measures cannot induce long-term water conservation

OLS: Ordinary Least squares; *GLS*: Generalized Least squares; *2SLS*: Two Stage least squares; *BG*: Between-GROUP estimator; *FE*: Fixed-effects estimator; *GMM*: General Method of moments; n.a.: not available or not applicable

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