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An Econometric Analysis of Residential Water Demand in Cyprus

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Abstract This paper analyses econometrically residential water demand in the three major urban areas of Cyprus, a semi-arid country with medium to high income levels. Water demand turns out to be inelastic, but not insensitive, to prices; price elasticity is less than unity in absolute terms, but significantly different from zero. The analysis further shows that periodic interruptions in household water supply, which were applied as an urgent water saving measure in 2008–2009, did not encourage water conservation among the population. The paper discusses these results, pointing at the need for appropriate water pricing policies and long-term planning in order to move towards sustainable water resource management.

Keywords Conservation · Elasticity · Household demand · Scarcity · Water shortage

1 Introduction

Cyprus is a small island state in the Eastern Mediterranean with a population of about 800,000, which became a member of the European Union (EU) in 2004. It has enjoyed sustained economic growth in the last three decades, and its per capita Gross Domestic Product (GDP) exceeded 20,000 Euros in 2009. Like other Mediterranean countries, it has a semi-arid climate associated with limited water resources. Agriculture remains the dominant water user in the country, accounting for two thirds of total water use, while the domestic sector, including tourism, accounts for 25 % (Zoumides and Zachariadis 2009).

Besides the fact that drought incidences have increased both in magnitude and frequency in the island during the last decades, regional climate models (Hadjinicolaou et al. 2011) forecast substantial temperature increases and somewhat lower precipitation levels, which are expected to have serious consequences on the (already scarce) water resources of the country.

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Apart from supply-side measures such as construction of dams, water recycling and desalination plants, it has become evident to national policy makers that demand-side measures are necessary in order to move to a sustainable management of water resources. Appropriate water pricing, which should incorporate in end-user prices the marginal scarcity and environmental cost of water use in a region, is a major demand-side measure promoted by the European Union's Water Framework Directive, which has started being implemented in Cyprus – although price levels are well below those which would be necessary in order to account for the actual scarcity costs in the island (Zachariadis 2010). A main barrier for the adoption of proper water prices in the residential sector is the common perception among policy makers that prices do not affect water demand – in technical terms that the elasticity of water demand with respect to price is nearly zero. Proper empirical examination of local demand patterns can shed light into this hypothesis. The available literature shows that, although residential water demand is inelastic to prices, its elasticity is not close to zero but lies in the range of -0.2 – -0.7 – see e.g. the surveys of Arbués et al. (2003); Dalhuisen et al. (2003); Olmstead and Stavins (2008); Schleich and Hillenbrand (2009), and Worthington and Hoffman (2008).

This paper presents the results of an econometric analysis of residential water demand in Cyprus, the first of its kind in the country, based on estimates from a set of data – many of them unpublished – collected from national and local water supply authorities. It is the first part of a wider project that attempts to estimate household water demand through a combination of cross-sectional and time series data. Although extending over a relatively short period (2001–2009) because this was the longest period for which all local authorities could provide complete datasets, a particularly interesting (and quite rare) aspect of the analysis is that it includes a 21-month period of severe water shortages, which have led to significant restrictions in household water supply. Therefore, the objectives of this paper are twofold: to determine the effect of income and prices on water use; and to examine to what extent these supply disruptions have affected actual residential water consumption.

The next sections report the data used, the methodology applied and the results. The last section discusses the implications of these results for water management policies in the country which, as explained in the concluding section, are also applicable to other industrialised semi-arid regions of the world.

2 Methodology and Data

Cyprus has three main urban areas, Nicosia, Limassol and Larnaca, accounting for 90 % of the urban population of the country. Water supply to households in each one of these areas is managed by a different Municipal Water Board (MWB). Information was collected from each one of the three MWBs in order to estimate seasonal water demand per household. Each MWB charges consumers for different periods: the Nicosia MWB issues bills every 2 months, the Limassol MWB every 4 months, and Larnaca's Board every 3 months. In order to make the minimum possible assumptions about monthly consumption by area, the information of all MWBs was aggregated in quarterly (4-month) data. The model has the following general form[1]:

$$q_{it} = f(income_{it}, price_{it}, pfix_{it}, temperature_{it}, rainfall_{it}, dummy_i) + \varepsilon_{it} \quad (1)$$

[1] Alternative specifications were also tested, with time trends, seasonal dummy variables and time lags of several independent variables, but none of these turned out to be statistically significant.

where f is a linear function and all variables are expressed in natural logarithms so that each variable's coefficient corresponds to the respective elasticity.[2] i denotes the district ($i = 1$ to 3 for each one of the three cities mentioned above), and t corresponds to a 4-month period, from the first quarter of year 2000 to the third quarter of year 2009. q is the actual (billed) quarterly water consumption per household in cubic metres (c.m.), *income* is quarterly income per household in each city (in Euros), and *pfix* is the fixed part of the water tariff (in Euros) for each quarter. *temperature* and *rainfall* are average temperature & rainfall levels (in degrees Celsius and millimetres of rainfall respectively) for each period and region. The dummy variables have been included to account for the fact that, due to severe water shortages, there have been substantial interruptions of water supply to households throughout the period April 2008 to December 2009 – water was available to each household for about 12 h every 2 days. There is a separate dummy for each district i, although the water supply restrictions were the same across all three MWBs, because these disruptions seem to have had different effects in each city, as will be shown in the next Section. ε_{it} is an independently and identically distributed error term.

Variable *price* denotes residential water price, in Euros per c.m. For historical reasons, each one of the three MWBs implements different tariffs, with tariff levels varying by up to 100 % from one city to the other. Each MWB applies some kind of incremental block pricing in order to encourage water conservation. Due to the existence of both a fixed portion in end user prices and block pricing, average water price is different than the marginal price. There is an extensive discussion in the available literature about whether consumers respond to average or marginal water prices (e.g. Nataraj and Hanemann 2011; Schleich and Hillenbrand 2009). Both effects were examined in this analysis and hence two models were formulated, with *price* representing average price in the one case and marginal price in the other case.

The water pricing system generates an endogeneity problem since prices are determined by the actually consumed water quantity and thus prices are correlated with the error term. Hence ordinary least squares (OLS) estimation of Eq. (1) will lead to biased and inconsistent results. Therefore the two-stage least squares (2SLS) method was applied using instrumental variables. In the first stage of this method the endogenous variable is regressed on a set of variables which are not correlated with the error term but are highly correlated with the endogenous variable. The value of the endogenous variable predicted at this stage is then used in the second stage, in an OLS regression, as an explanatory variable in place of the endogenous variable. In the case of model (1), after several discussions with the economic departments of all MWBs, it was assumed that MWBs determine their tariffs every year on the basis of a) their water sales costs in the previous year (expressed in Euros per c.m. of water), b) the corresponding sales costs forecast for the current year, and c) the consumer price index (*cpi*) of the previous year, which is used here as a proxy of the rise in their labour and other operational costs. Therefore, these three variables serve as the instruments in the first stage of the 2SLS estimation:

$$p_{it} = g\left(salescost_{it}, salescost_{i,t-1}, cpi_{t-1}\right) + u_{it} \tag{2}$$

where g is a linear function and u an independently and identically distributed error term.

[2] The specification assumes that elasticities are constant throughout the sample. This is a simplification because consumer response (expressed in elasticities) will probably be different at very different income or price levels, but the available dataset is not rich enough to enable the use of more complex model specifications that allow elasticities to vary.

For estimating Eqs. (1) and (2), the necessary data were obtained from multiple official sources, which are summarised in Table 1. Descriptive statistics of each variable are provided in Table 2. Figure 1 illustrates the evolution of billed water consumption per period in the three urban areas examined. It is not straightforward to compare water use per household in the three areas based on Fig. 1 because each Municipal Water Board issues bills for periods of different duration. However, if one aggregates seasonal bills (not shown here), one can notice that there are important differences in water use per area: households in Limassol consume more water than those in Nicosia, although average income in the former city is lower than in the latter. At the same time, due to the abundance of local water resources in Limassol which provided the local population with cheap water, this city had historically lower water charges than Nicosia and Larnaca. The combination of lower prices with higher per household consumption is already a qualitative indication of the importance of prices for water use; whether this is quantitatively confirmed is a matter of the econometric estimations presented in the next Section.

Note that, as mentioned above, there have been serious disruptions in water supply in all three areas between April 2008 and December 2009; however, Fig. 1 shows that – with the exception of the Limassol area – these restrictions in supply do not seem to have led to similar substantial reductions in water consumption. This issue will be further examined in the next Section.

3 Results

Table 3 displays the results of the 2SLS estimation with two models, one using the average price variable and one with the marginal price variable. The effects seem to be in line with economic theory and the available literature, and are particularly consistent with the econometric results of similar models estimated for European countries in recent years (Di Cosmo 2011; Martínez-Espiñeira 2007; Musolesi and Nosvelli 2007; Frondel and Messner 2008; Rinaudo et al. 2012; Schleich and Hillenbrand 2009). As expected from theory,

Table 1 Data sources

Variable	*Data used*	*Source*
q	Billed water consumption per period for residential consumers	Municipal Water Boards (combined information from annual reports, financial accounts and unpublished data made available to the authors)
	Number of consumers per period	
Price, pfix	Water tariffs (fixed prices & prices per consumption block)	
	Fraction of consumers in each consumption block	
Salescost	MWB revenues and expenditures	
Temperature, rainfall	Monthly temperature and rainfall	Cyprus Meteorological Service
Income	Quarterly GDP, population and consumer price index	Cyprus Statistical Service (annual and periodic publications)
	Household income by district of Cyprus	Family Expenditure Surveys from Cyprus Statistical Service (processed by the authors)

Table 2 Descriptive statistics of the variables used

Variable	Mean	Std. Dev.	Min	Max
Quarterly water consumption per household (c.m.)	40.8	1.1	30.3	57.3
Quarterly fixed water tariff (Euros)	11.6	1.3	8.2	20.8
Average water price (Euros/c.m.)	0.58	1.48	0.17	1.12
Marginal water price (Euros/c.m.)	0.63	1.69	0.16	1.43
Household income (thousand Euros)	18.1	1.2	13.0	24.0
Average quarterly temperature (degrees Celsius)	19.5	1.3	12.3	28.1
Average quarterly rainfall (millimetres)	16.8	4.4	0.2	83.2
Consumer price index (2005 = 100)	100.9	6.8	87.8	111.9
Cost of water sales (Eurocents/c.m.)	42.0	13.4	25.6	78.0

income elasticities are significant but less than unity, implying that residential water is a necessity for households. Higher temperatures tend to increase water consumption, and so do higher rainfall levels, although the latter coefficient is very small.

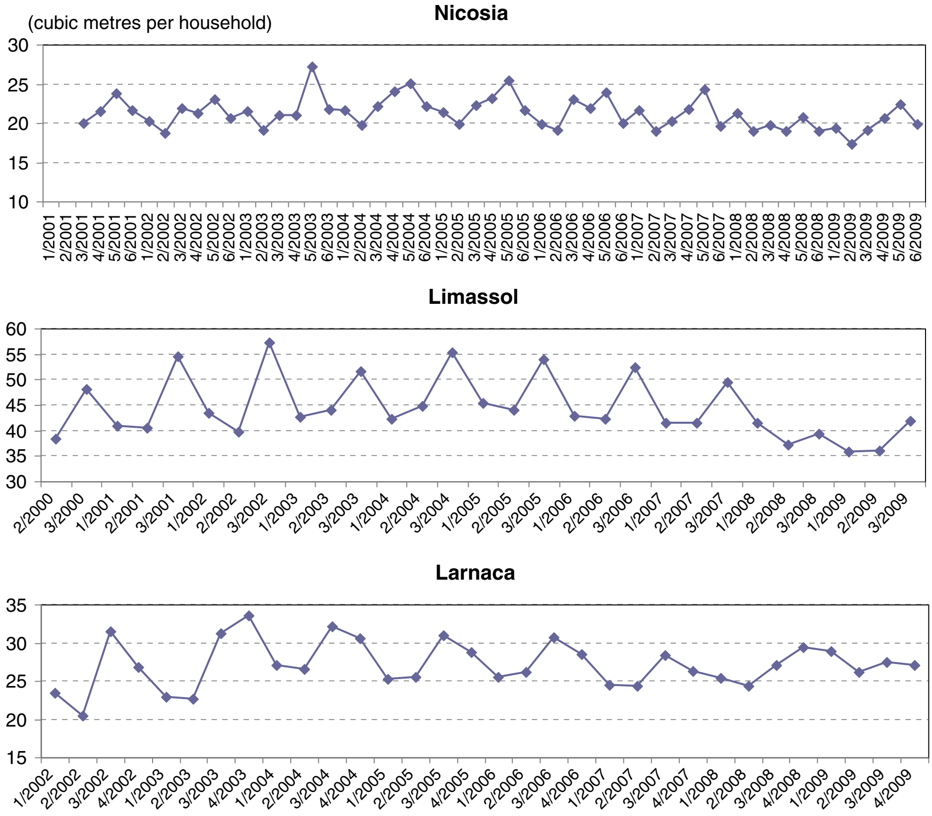

Fig. 1 Billed residential water consumption per household in the three urban areas of Cyprus between years 2000 and 2009. Data for each area are shown in different time steps because each Municipal Water Board issues bills for periods of different duration

Table 3 shows also that – in line with economic theory – the higher the water tariffs the lower the consumption per household, which holds for both the fixed and the variable part of the water price. Most importantly, the average price elasticity turns out to be significant and equal to -0.25, whereas marginal price elasticity is estimated at -0.45. Even if one assumes that consumers do not observe marginal but average prices, still the price elasticity is not negligible, so that appropriate water pricing (i.e. pricing that includes the marginal scarcity and environmental cost of water use) can lead to substantial water conservation. Although these elasticity values are within those reported earlier in other studies mentioned above, it is nonetheless important to mention this result here because water managers in Cyprus tend to underestimate the effect of prices on household water demand because they believe that relatively well-off people in a country with water shortages are not willing to change their consumption patterns because of prices.

The second interesting result of Table 3 is related to the effect of water supply disruptions on residential water use. As Fig. 1 shows, and the econometric estimations formally confirm, the serious interruptions in continuous water supply of years 2008–2009 have not affected significantly the water consumption of households in two of the three urban areas; only for the city of Limassol is the dummy variable statistically significant, where water consumption has decreased by 19–25 % compared to what it would have been without these disruptions. In other words, although water authorities provided about 30 % lower quantities of water during that period, most households

Table 3 Estimation results (standard errors in parentheses)

Variable	Coefficients of average price model	Coefficients of marginal price model
Income	0.529***	0.753**
	(0.193)	(0.332)
Price	-0.248***	-0.449***
	(0.055)	(0.141)
pfix	-0.441***	-0.490***
	(0.054)	(0.080)
Temperature	0.241***	0.292***
	(0.057)	(0.076)
Rainfall	0.047***	0.062***
	(0.011)	(0.016)
Water disruptions dummy, Nicosia	-0.034	-0.025
	(0.050)	(0.065)
Water disruptions dummy, Limassol	-0.193***	-0.253***
	(0.058)	(0.089)
Water disruptions dummy, Larnaca	0.065	0.088
	(0.054)	(0.071)
Constant	-1.346	-3.746
	(1.854)	(3.255)
Sample size	73	73

** and *** denote statistical significance at 5 % and 1 % level respectively were not affected.[3] This can be explained by the fact that all houses in Cyprus possess water tanks of sufficient size, which are filled up during normal operation of water supply and can satisfy a household's water needs for 1 or 2 days. During the time of a water supply disruption a household uses water from this tank, and the tank is filled again when public water supply is restored. As a result, the main consequence of limited water supply quantities was that household water tanks were not entirely full all the time, but were enough to satisfy residential water needs. A second explanation, offered by technical staff of MWBs, is that the losses in the entire urban water distribution network were reduced during the period of interrupted water supply because the network was under reduced water pressure; the reduction of losses may have been different from one city to the other because of different physical characteristics of the water network in each city (e.g. altitude of parts of some urban areas, length of the network etc.). Whatever the reasons for this effect, it is evident that urgent water saving measures such as periodic interruptions in water supply can alleviate temporarily a problem of water shortage, but cannot induce long-term water conservation among consumers, which is important for sustainable water management.

4 Conclusion and Implications for Water Management Policies

This short study attempted to analyse residential water demand in Cyprus, a semi-arid country with medium to high income levels, using available (but largely unpublished) local data and proper econometric methods. The applied model exploited the variability in water tariffs charged by each local water authority in order to identify the effect of income and prices on water use. Two interesting results were found. Firstly, water demand is inelastic, but not insensitive, to prices; price elasticity is less than unity in absolute terms, but significantly different from zero. Secondly, periodic interruptions in household water supply, which were applied as an urgent water saving measure in 2008–2009 due to severe water shortages and lack of a proper long-term water management strategy, did not encourage water conservation among the population.

Although these findings are not surprising, they are very useful for water managers and planning authorities to keep in mind. In current and future conditions of water scarcity, many nations cannot meet demand through increased water supply only; water demand management is therefore imperative. Supply side measures such as reduction in losses and leakages of water distribution networks as well as demand side measures such as subsidies for installation of water saving equipment and consumer awareness campaigns are frequently applied by water authorities. These activities are very useful and constitute a necessary part of a water conservation strategy, but their implementation often requires funds that countries may not possess in times of restricted public finances. On the other hand, water pricing is a major demand-oriented policy instrument that can contribute to efficient water use by encouraging consumers and firms to adjust their water use behaviour. Even in high-income semi-arid countries, proper water pricing can make a difference and induce water conservation, particularly in the medium and long term. As shown by Zachariadis (2010) in the case of Cyprus, the cost of inaction in demand-side measures can be high.

Therefore, appropriate water pricing policies, which incorporate in end-user prices the full cost of water use (including marginal scarcity and environmental costs), and long-term planning are critical ingredients of sustainable water management policies. Apart from

[3] Note that there was essentially no change in water prices during the period of disruptions.

encouraging water conservation, proper pricing schemes can provide much needed public revenues which can finance investments or subsidies in water-saving measures. According to the Organisation for Economic Cooperation and Development, environmental and natural resource taxes and charges are among the most promising measures to improve public finances without being detrimental to economic growth (Hagemann 2012). Therefore, policymakers around the world should seriously consider including carefully planned water prices and charges (along with the other technical measures mentioned above) in future policy measures. If such pricing schemes have adverse social implications because they put a heavy burden on low-income households, this can be tackled by authorities through appropriate compensations to these households.[4] In any case, in most of the industrialised world, costs for water services represent a very small fraction of total household expenditures (OECD 2009) and therefore are unlikely to cause serious social problems.

Finally, it is important to stress that efficient pricing should also be implemented in the agricultural sector, which – as in all Mediterranean countries and in many regions across the world – consumes most of the water in the country with often questionable economic benefits. Pricing reforms in line with the requirements of the EU Water Framework Directive proceed more slowly in the case of agriculture, which is a sensitive sector for social, political and environmental reasons. To what extent adequate agricultural water supply should be ensured and at what prices is a major topic for further research.

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