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ESTIMATING URBAN RESIDENTIAL WATER DEMAND DETERMINANTS AND FORECASTING WATER DEMAND FOR ATHENS METROPOLITAN AREA, 2000-2010

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Abstract
Aiming at sustainable water resources management and use, the current water policy requires an essential analysis of water demand formulation and evolution. In this context, the present paper considers the city of Athens in Greece, where domestic water use is analyzed, estimated and forecasted. The policy-relevant variables, mainly income and water prices, are systematically considered and their effects on water demand are appraised. The study concludes that a drastic increase in water demand induced by increasing income will occur, while the economic instruments have little potential to influence water use.

JEL Classification: Q50
Keywords: Water economics, Urban water use, Water prices, Water demand, Athens water use.

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1. Introduction

The continuously intensifying scarcity of water resources is a crucial problem in almost all contemporary societies. Even in areas where there are adequate quantities of water, the problem of scarcity is usually confronted through the deterioration of water quality resulting in increasing costs for certain - mainly indoor - water uses. The problem of water scarcity has manifested itself in different ways in recent years. The most common ways are: a) increased cost of water usage, b) intensified competition over access to water resources and c) social insecurity (breakout of diseases) due to the lack of water.

The traditional policy, which dominated the 20th century and aimed at confronting the scarcity of water, depended on utilizing new water resources. Technological advancement and economic growth accentuated water transferability from remote sources, as a practical and relatively inexpensive practice. The socio-economic benefits of transferring water were greater than the costs of exploiting new resources and therefore the so-called supply policy prevailed. However, the efficacy of such a supply-side measure is nowadays questionable, since the extensive use of water resources has increased globally. Indeed, the hunt for new water resources would have continued indefinitely if it had not reached an impasse: water resources are finite and therefore eventually a continuously increasing number of potential users would be competing for a given number of resources, as all these potential users are acting on the basis of water supply policy.

This impasse becomes more intense as the demand for water supplies continuously increases, pushed upward by the following main factors: a) increases in population –those already experienced and those anticipated–, b) economic growth and c) western life-styles.

The problem is more severe as far as domestic use is concerned. Domestic use requires certain qualitative characteristics related to human health. Therefore, although domestic use accounts for 10% of total water use, the availability of appropriate water resources is limited and the costs for domestic use are rapidly increasing.

In this context, there has appeared a new model of policy that aims at maximizing the benefits of the utilization of water resources already in use in order to minimize or even to eliminate the need for new water supplies (Baumann *et al*, 1998). This policy, defined as "water demand management", is gradually becoming popular, especially in developed societies. "Water demand management" mainly consists of the following actions: a) the minimization of losses in transport and storage systems, b) the reuse of water, c) the containment of water use by avoiding waste and d) the efficient use of water resources (Renwick and Archibald, 1998).

In the framework of demand management, it is vital to analyze and to understand the characteristics of water demand. How demand is formulated, which factors determine it, how demand responds to changes in income and relative prices and eventually how future demand will be shaped (Griffin and Sickles 2001, Arbues *et* *al.*, 2003). As a result, the analysis of demand is an essential component in designing effective water demand management.

Furthermore, the analysis of water demand is crucial in determining water prices and evaluating investment projects, both issues of extreme importance in current water policy (OECD, 1998). In this context, the analysis and forecasting of water demand is of significant importance in designing and implementing effective policies.

The present paper examines demand analysis in a region with specific characteristics such as: intensified scarcity, frequent and lasting drought periods, expanding urbanization etc. Indeed, the Athens metropolitan area presents water issues representative of many other urban areas. The paper focuses on domestic use, since it appears to be the more problematic -requiring water of high cost and of severe scarcity- because of the quality standards which have to be met.

The structure of the paper is as follows: In the first section some fundamental water economics are presented as a basis for further analysis. In section two, the methodological framework for analysing and forecasting water demand is briefly discussed. The scenarios and their derived results are presented in section three. A summary and conclusions are presented in the final section.

2. Theoretical basis

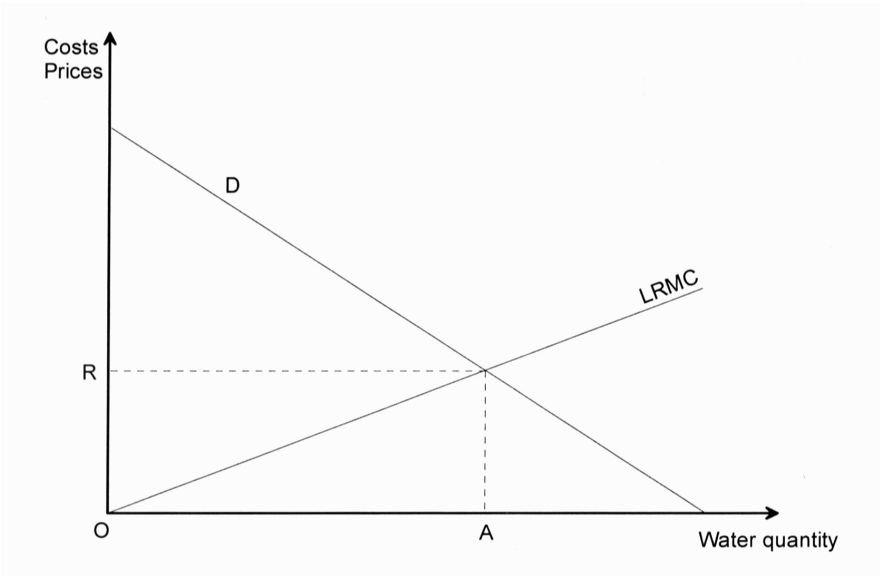
Water Demand Analysis and Water Pricing

Essentially, the analysis of water demand aims at offering all the necessary information and knowledge for designing an effective water demand policy, and specifically a policy that pursues the efficient use of water resources. Accordingly, efficient use is defined as a pattern of use that maximizes the benefits arising from the exploitation of water resources (Tietenberg 1991, Pearce 1999). A pure competitive water market would ensure efficient use by defining the optimum use of water and its optimum allocation among competitive users.

Indeed, in a market that operates under competitive conditions, the price of water would be determined by the interaction of market demand and supply to reflect the actual costs of water usage. This price would induce users to purchase the optimum quantity of water. In this context, no exogenous administrative intervention would be necessary, as the "invisible hand" would, by itself, ensure the efficient level of use induced by an equilibrium price that reflects water costs. Furthermore, the "invisible hand" would lead to defining the appropriate investments in order to attain the efficient use of water in the future. However, perfect competitive market conditions do not and probably cannot exist in the majority of cases (Briscoe 1997, Pearce 1999). In most cases, the supply of water is a monopoly whose characteristics closely resemble those of a "natural" monopoly. Specifically, the extremely high infrastructure costs for transporting, treating and delivering water make difficult the operation of multiple water suppliers.

The economic characteristics of the water sector, in combination with the fundamental social perception that water is a socially sensitive good related to human existence and health, led to a strict administrative framework for the operation of the water supply sector and hence of the water market (Kaika 2003, OECD 1989). In effect, the fundamental decisions, like the determination of investments and prices, have been strongly influenced by administrative rationale. In such a framework of direct or indirect government interventions, the estimation of demand parameters and characteristics acquires a special significance, since the decision-makers require sufficient knowledge and information. Furthermore, if the objective of water policy is to ensure socially efficient use, demand analysis is a precondition of designing such a policy, since it defines the optimum socioeconomic water use and the respective water price (Martiner-Espineira *et al.* 2004, Espey *et al.* 1997, Arbues *et al.* 2003). The conditions for determining the efficient use of water and the relevance of demand analysis, which offers the necessary information, are traced through Figure 1.

Figure 1. The efficient use of water resources



In Figure 1 curve LRMC represents the long-term marginal cost of water supply. The data and the information for the estimation of the LRMC curve are, to a significant level, available to the administrative agencies responsible for formulating water policy. However, the authorities are hardly aware of the functionality and operationability of the long run (marginal) costs of water supply. Curve D represents the marginal benefits of water use. However, the information for defining curve D could be revealed in a free water market as well as through market surveys in the administratively supervised markets. If a competitive market exists, then the curve D defines the respective demand curve. The efficient use of water is determined by the intersection of the LRMC and D curves. OA represents the efficient quantity of water use (Tietenberg 1991, Pearce 1999). In this light, the efficient optimum use of water would have prevailed in a competitive market. In the administratively regulated markets, the achievement of effective use, OA in Figure 1, can be ensured if the decision makers define the appropriate price, OP, being equal to the marginal cost of OA water use. To define the appropriate price, decision-makers should have sufficient information on water demand. This information is not directly available through the function of the existing water markets functioning under administrative supervision.

Furthermore, the analysis of demand can be an important tool in formulating the relevant investment policy. The key factor for making appropriate investment decisions is the expected (future) demand. Forecasting demand leads to the determination of the optimal future level of water use and hence to the design of the future capacity of the water supply system (delivery networks and processing plants). Water supply infrastructure is considered to be expensive, especially as far as urban uses are concerned. Therefore, the forecasting of water demand, and the definition of the level and the appropriate magnitude of investments, is of crucial importance for the decision-makers.

3. The Methodological Framework

The determination of the variables that influence domestic water demand constitutes an essential ingredient for designing pricing policies in the domestic water supply sector (Martinez-Espineira 2002, Arbues *et al.* 2003). A lot of work has been devoted during the last few years to the specification and estimation of residential water demand functions (see Nieswiadomy and Molina, 1989, Renwick and Archibald 1998, Hansen 1996, Nauges and Thomas 2000, Martinez-Espineira 2002, etc.). Almost all previous work has been based on annual time series while the water demand appears inelastic but not perfectly inelastic (Martinez-Espineira 2002, Arbues *et al.* 2003, Martinez-Espineira 2004). Unfortunately, there is no such study for the case of Greece and in particular for the metropolitan Athens area, which presents several representative characteristics of the Mediterranean urban water systems.

Consumption patterns for residential water in Greece and in particular in the metropolitan Athens area have changed over time due to increases in income and prices and other shift variables variations (i.e. weather and more precisely temperature). As mentioned in the previous sections, analysing and forecasting such changes in demand for residential water use over the long term is of interest to a wide variety of planning studies (Luay- Froukh 2001, Dalhuisen *et al*. 2003). For example, the Athens Water Company together with the national government are interested in analysing the current consumption patterns as well as predicting the future level of demand for designing optimal investments as well as pricing policies.

There are several approaches to forecasting water demand (Granger, 1980, Gardiner and Herrington 1986, Luay-Froukh 2001,). Empirical models can take into account the effects of earlier events and as a result they can even explain the past fairly well (Arbues *et al.* 2003, Dalhuisen *et al.* 2003). However, new unforeseen events will occur and the future will always appear more uncertain than the past (Clements and Hendry 2003). Furthermore, as Clements and Hendry (2003) note, the economic forecasts end as a mixture of science - based on econometric systems that embody consolidated economic knowledge - and art, namely judgements about perturbations from recent unexpected events.

Single equation water demand estimation may not need to be an *ad hoc* assumption. Following a standard dual approach, we assume an underlying structure of consumer preferences based on a Stone-Geary utility function. The model is based on the static theory of optimising household behaviour assuming similarity of preferences, homogeneity of goods and perfect information (Mertinez-Espineira *et al.,* 2001).

In particular, the approach adopted in this paper is based on the hypothesis that all available sources for consumption are distributed evenly. According to microeconomic theory, the individual choice is conceived as an interrelationship among the quantity of goods that the consumer wishes and is able to buy in terms of price, p, income, y, his preferences as well as social and demographic characteristics. In other words, the consumer divides his income between quantities of goods and services, q, so that an increase in the utility level, u, derived by the individual consumption, is ascribed as:

$$\max u = u(\mathrm{q}),\ pq = \mathrm{y} \quad pq = \sum p_i q_i$$

Using the appropriate substitutions, the demand functions are obtained by simple differentiation as follows:

$$\ln D = \beta_i \sum C_{ij}\, ln\, P_j + \sum \gamma_{ik}\, ln\, Z_k \tag{2.1}$$

where, lnD is the logarithm of the corresponding demand, ln*P* is the logarithm of the price of residential water and lnZ other shift variables (income, trend, etc.).

A two-stage procedure is applied in order to forecast future water demand. In particular, the first stage consists of the econometric model previously described and in the second stage a synthetic model is constructed for conducting policy-relevant simulations. The current simulation is based on a model where the pattern of water consumption is the endogenous variable and price, income, and a weather index are the main determinants of the system. The functional form of the equations and the parameters needed for forecasting purposes are derived from equation 2.1. The model is then calibrated for the base year (1999, in this case) and the simulations are run using the calibrated term together with the parameter estimates.

4. The case study – Estimations Forecasts and Results

Athens has been the capital of Greece since 1834, and its population of 3,079,922 inhabitants accounts for 35% of the country's population. Athens has a typical Mediterranean climate with a mean temperature at 18.5°C and mean total precipitation of 388mm, but in summer this is virtually non-existent. Humidity is 50% in July and the average maximum temperature is 31°C in August. Athens is located in a dry and arid area. Nowadays, water is almost exclusively provided by the Athens Water Company, which until recently was under government management. The state is still the main decision-maker for water policy (Metron, 2000).

The paper examines domestic water use in the greater Athens area. Domestic use in Athens includes all households and small professional uses (commercial and institutional). Domestic use accounted for 67% of total water use in 1998 and therefore its evolution is crucial for the sustainable management of water in Athens. Furthermore, the case of demand for water in the city presents some interesting recent history: the drought period of 1990-93. From May 1990, emergency measures were taken; water prices were increased and as the public realized, through strict administrative measures and extensive media coverage, the severity of the water scarcity, demand decreased steadily year by year to reach its lowest level in 1993.

In 1992, domestic water prices were increased by 100%. Nevertheless, the scarcity of water was becoming critical and in 1993 legislation was passed introducing quantitative limitations for water use and establishing high penalties in case of violation.

In this context, water demand management is of paramount importance for the sustainability of the Athens water system. The calculated annual increase in water use during the last few years contrasts with the safe yield of the resources system - which is between 530 - 580 Hm^3/year (Metron, 2000).

In order to estimate water demand determinants, annual time series on residential water demand for the metropolitan Athens area and relative prices were obtained from the Athens Water Company for the period 1981-1999.

According to the methodology described in the previous sections, the following specification for the residential water demand function is obtained:

$$D_w = \alpha + \beta_i \ln P_w + \gamma_i \ln ln + \delta_i \ln X + \varepsilon_i$$

where D_w stands for the quantity of residential water demanded, P_w for the water price, in real disposable income, X for the vector of other variables (in this particular case a trend variable as a proxy to weather variations) and ε the error term. Moreover, price and income are expressed in real terms using CPI as the deflator. It is important to stress that *per capita* real GDP was used as a proxy for the available income and the size of the population was used for deriving *per capita* measures.

The results of the econometric analysis are presented in Table 1. In particular, all variables have the expected, from the literature, signs and are statistically significantly different from zero (t-statistic), the explanatory power of the model is high (R^2 and R^2 adjusted) and finally, no problem of first order autocorrelation is apparent (2.2) (Durbin-Watson).

Table 1. Econometric Estimations

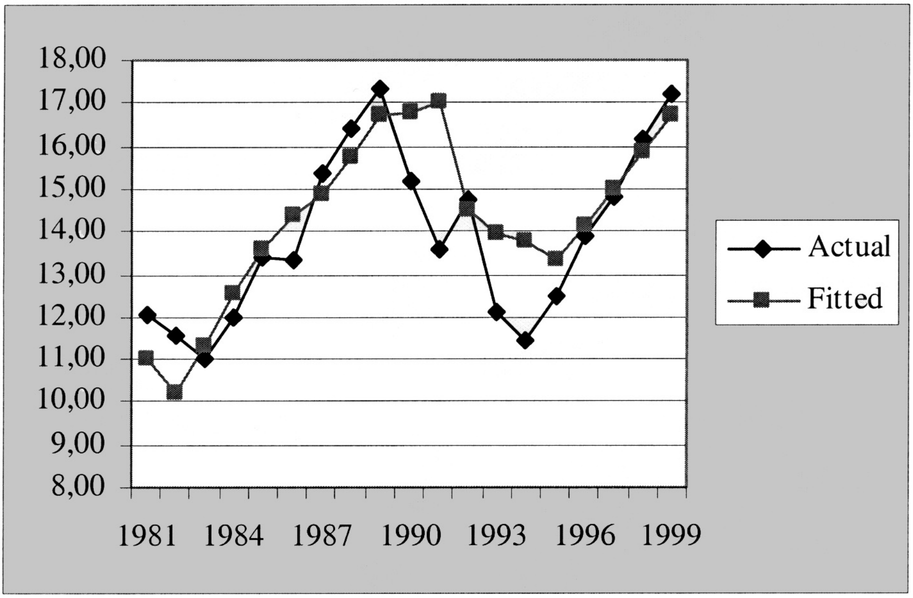
	Coefficients (Elasticities)	Std. Error	t-Statistic	P – Value
Constant	1.04	0.71	1.46	
Real GDP*	0.72	0.39	1.86	0.067
Real Water Price (One Year Lag)	-0.10	0.03	-3.78	0.012
Trend	0.25	0.04	6.27	<0.001
Dummy Variable for 1992	-0.14	0.05	-2.79	0.015
Dummy Variable for 1994	-0.22	0.05	-4.33	0.001
R-squared	0.95	Durbin-Watson	2.26	
Adjusted R-squared	0.91	F-statistic	2.44	

Source: Estimated
**Note:* real GDP refers to *per capita* real GDP

The elasticities obtained from the present model are also presented in Table 1. Specifically, the residential water price elasticity is very low, which is also the outcome of previous research for other countries, (Martinez, 2002) a finding that could be partly explained by the fact that household expenditure on water is a very small fraction of its total expenditure. So, if the government, for scarcity reasons, decides to reduce actual water consumption, tariffs are not a very effective policy measure. The income elasticity is less than unity but much higher than the own price elasticity. Thus, as income increases, accordingly, the demand for residential water will increase by a smaller proportion. Finally, the trend variable, which has been used as a proxy to weather variations presents an elasticity of 0,25, a fact which emphasizes that weather variations are far more important than price ones.

As mentioned, in this study a two-stage procedure is applied. More precisely, in the first stage the price and income elasticities as well as the coefficient of a trend variable are estimated with annual data for the metropolitan Athens area. In the second stage, the estimated elasticities are used in a synthetic model for conducting simulations regarding future evolution of residential water demand.

Figure 2. Actual and Fitted Values - *Per Capita* Consumption of Residential Water



Source: Estimated

In order to assess the credibility of results, the model was run over the sample period (1981-1999). In Figure 2, comparisons between actual and fitted values are presented. It is clear that conducted simulations capture the actual time path of the variables reasonably closely. Additionally, two statistics for examining the forecasting accuracy, namely the root mean square percent error (RMSPE) and the mean percent error (MPE) are reported. The statistics suggest (the RMSPE is equal to 0,01 and the MPE is equal to –0,01) that the model tracks historical developments in water demand patterns fairly well. Overall, the results for both stages can be considered promising, a fact that permits us to continue with the post sample prediction through policy scenarios.

In order to be able to recognise the possible policy and theoretical implications of the results, it was considered important to conduct a sensitivity analysis. Three scenarios were examined. The first scenario considers the EU projections for private consumption expenditure, an increase of 3% per annum for Greece, and introduces these changes in the expenditure side of the equation. In this scenario, real prices are assumed to be fixed for the period 2000-2010 and the trend variable which is used as a proxy for temperature variations, is also assumed fixed in the base year. The second scenario considers the same growth of 3% per annum, while, in 2003 a tariff of 10% in residential water usage is applied (trend is assumed fixed in the base year). Finally, in the third scenario the growth rate is again 3%, but in 2003 the Water Company decides to reduce prices by 10%.

The results are presented in Table 2 and in Figure 3 and show an increase of *per capita* residential water consumption in all scenarios under consideration. This outcome can be considered as important and it is mainly the result of the increase in available income. More precisely, a 3% increase in the real GDP will drive consumption upward by 2.5% per annum (an overall 24.6% increase over the 2000-2010 period). In addition, the same, more or less, results are obtained from the other two scenarios. Namely, the reduction of water price by 10% will lead to a 2.6% annual increase in demand and a tariff of 10% to a 2.4% annual increase.

The policy implications related to the simulation results are quite obvious. More precisely, prices could not be considered as a major policy tool (the own price elasticity is low and equal to –0.1) since their variation (increase or decrease) will have a minor impact on water consumption.

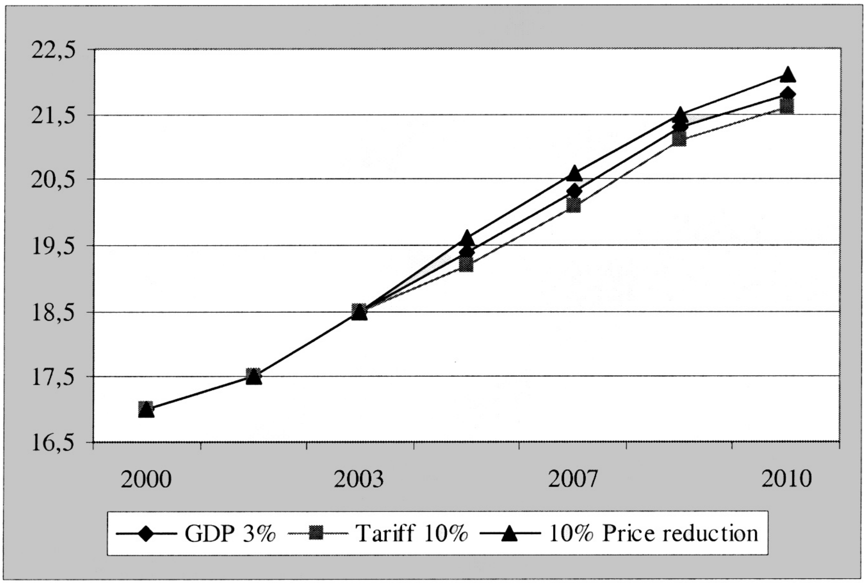
Overall, these results can be used as a policy tool for designing effective strategies for sustainable water use. Since, income increase is expected over the next few years, its effect on water usage must be counterbalanced through certain measures.

Table 2. Simulation Results

	3,0% Increase in Real GDP	***Tariff 10%***	**10% Price Reduction**
2000	17.0	17.0	17.0
2001	17.5	17.5	17.5
2003	18.5	18.5	18.5
2004	18.9	18.7	19.1
2005	19.4	19.2	19.6
2006	19.9	19.6	20.1
2007	20.3	20.1	20.6
2008	20.8	20.6	21.0
2009	21.3	21.1	21.5
2010	21.8	21.6	22.1
Average Annual Change (%)	2.5	2.4	2.6
Total Change (%)	24.6	23.4	26.1

Source: Estimated

Figure 3. Alternative Scenarios for *Per Capita* Residential Water Demand



Source: Estimated

5. Conclusions

Growing water scarcity requires sustainable water use - especially in urban areas where domestic use requires high quality characteristics. To design effective water policy, urban water demand should be sufficiently analysed and broken down. The case of the Athens metropolitan area presents certain interesting aspects in this context. In the Athens area, the population density is relatively high, the climatological conditions lead to intensified water use, while water resources are substantially scarce and the various economic growth scenarios alter water use patterns and habits. Indeed, The Athenian water system will face severe problems in the future, if current trends continue. In this context, to design a sustainable water policy is vital for the future of the city.

The present paper identifies the factors that determine water demand in Athens. Future demand is estimated under certain plausible assumptions concerning its crucial determinants. We conclude that water use will increase regardless of the evolution of water prices in the future, since income elasticity is more sensitive than price elasticity.

If correct, these conclusions could lead to policy-relevant recommendations. The most cogent is that water saving plans should be based on quantitative restrictions and on voluntary actions prompted by information campaigns focusing on increasing the environmental awareness of inhabitants. On the other hand, the paper creates prospects for further demand analysis and forecasting so that policy makers will be able to define focus groups and other factors that could shape an effective water demand policy.

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