Siep Società italiana di economia pubblica
XIX CONFERENZA

ECONOMIA DEL CAPITALE UMANO
Istituzioni, incentivi e valutazioni

Pavia, Aule storiche Università, 13 - 14 settembre 2007

THE EFFECT OF A TARIFF REFORM ON THE DEMAND OF WATER FOR RESIDENTIAL USES:
A PANEL DATA ANALYSIS OF WATER CONSUMPTION IN SARDINIA

VANIA STATZU AND ELISABETTA STRAZZERA

pubblicazione internet realizzata con contributo della COMPAGNIA di San Paolo

The effect of a tariff reform on the demand of water for residential uses: A panel data analysis of water consumption in Sardinia

VANIA STATZU[1] and ELISABETTA STRAZZERA

Dipartimento di Ricerche Economiche e Sociali and CRENoS
University of Cagliari

DRAFT –JULY 2007 –do not quote

Abstract

A panel of 240 Sardinian towns in a 6-years period is analyzed in order to identify the determinants of residential water demand and the effect of a tariff reform under conditions that can typically be found in Mediterranean and arid regions: quantity constraints imposed to sustain periods of drought; the presence of tourists in private residences that inflates the domestic consumption during summer months; inefficient management of the resource. Panel data techniques are employed to estimate the effect on the domestic demand of water of standard economic and structural variables, such as price, income, which are all found significant, in line with previous literature results. Moreover, we are able to estimate the effect that weather differences (both in spatial and temporal dimension), tourist presence in secondary residences, demographic characteristics and quantity restrictions have on the final consumption of water in the domestic sector. Furthermore we explicitly analyze the impact of the tariff reform in average consumption.

Keywords: water demand, water pricing, panel data

JEL classification: Q21, Q25, C23

1. Introduction

In the last two decades many countries, both in the developed and in the developing world, have experienced difficulties in meeting the requirements of an increasing demand for water. European countries, especially in Southern Europe, were not exempt from severe shortages, which constrained even basic levels of consumption. This situation led to the conference of Dublin (1992), where international institutions, governments, ONG and other involved institutions tried to rethink previous policies and management practices (Winpenny, 1994). The result was the Dublin Declaration (1992), which establishes that water has to be considered as an economic good in order to reduce water consumption at a level that actual water supply is able to satisfy. A strong debate on the consequences of this statement is still ongoing but water management policies have been strongly influenced by this philosophy all

---

[1] Corresponding author: Vania Statzu, CRENoS, via San Giorgio 12, 09123, Cagliari. Tel: +39 070 6756417; Fax: +39 070 6756402; e-mail addresses: vania.statzu@crenos.it; strazzera@unica.it

over the planet. A passage to the increasing block rate tariff system and to an increase of water prices has been supported by the European Union. The Directive 2000/60/UE and the COM(2000)477 aim at enhancing the sustainability of water management practices and policies introducing an increasing block tariff for all uses. In first drafts of the Directive also the agricultural sector was involved in this type of tariff reform but this turn was contrasted by agricultural lobbies. In the final version the adoption of a more efficient tariff system linked to consumption rate is only recommended in the agricultural sector, while in the residential sector the requirement is made stringent (Olsen (2001); Hrovatin and Bailey (2001)).

National laws adopting the price incentive principle were already in force in some member countries such as Spain (Kent et al. 2002) and Italy. Southern European countries are characterized by endemic conditions of water scarcity, which are lately getting even more serious. A general climate change, changes in land use, excessive pressure on ground water reserves, are all factors negatively affecting the regenerative properties of the water resource: in some cases even inducing a desertification process. On the other side of the market, a constantly increasing demand, especially in the domestic sector, increases the pressure, which in periods of drought becomes unsustainable. Periods of demand peaks - mainly due to high tourist pressure on small coastal municipalities during summer months - generate conflicts between uses. This picture describes well the situation in Sardinia, which we take as a case study in the present work.

In such context, a policy change, from interventions aimed at increasing the offer, toward policies aimed at controlling the demand, was designed by a national law passed in 1994 (LN 36/94, also known as Legge Galli). Before the reform took act, in Sardinia there were several water agencies for the domestic sector, each with its own tariff system: even though all agencies had an increasing block system, blocks and prices differed across agencies. After the water reform, a unique regional water agency has replaced the pre-existing ones, and a unique (increasing block) tariff is now in force for the whole regional territory.

The aim of this research is twofold: first, we aim to uncover the determinants of water demand and its elasticity to price and non price factors; second, we attempt to evaluate if the new tariff system introduced in Sardinia, with different block size and higher marginal prices, has been able to induce consumers to reduce water consumption.

The present work has some elements of novelty with respect to the existing literature on water demand based on panel data analysis: a large cross-section dataset; different price structures for some years, and then a unique price structure in the last year; a climate variable, the aridity index, which is more informative than other variables used in previous studies. We introduce estimates of the effect of “residential tourist demand”, which is usually overlooked in such analyses because of lack of data (cf. Martinez-Espineira, 2003), but can be important to explain water consumption. Furthermore, the period under analysis includes years of drought, which are characterized by impositions of quantity restrictions in the water service, and regular years, with good or satisfactorily levels of rain, and no restrictions in the water service: we are able to use a “restrictions” variable based on the effective hours of restrictions, which is more informative than the qualitative dummy variable used in other studies.

There are only few previous studies using Panel data analysis in Europe (Mazzanti and Montini in Italy (2004), Hoglund (1999) in Sweden, Nauges and Thomas (2000a e 2000b; 2003) in France and Martinez Espineira (2003)) in Spain. As in Hoglund (1999), we adopt both the static and the dynamic approach for estimation of our panel data.

The paper is structured as follows: the next section contains a survey of previous panel data studies on the domestic demand of water; section 3 illustrates the econometric methods; section 4 presents the case study; section 5 describes the data; the results are discussed in section 6; finally, section 7 concludes the paper.

2. Panel data models for residential water demand: an overview

The econometric analysis of the demand of water for residential uses has been prevalently focused on survey data of individual consumption, specifically collected to analyze the price and income elasticities with the aim of obtaining useful information for optimal tariff policies. Part of the literature focuses on the comparison of different tariff systems and related consequences of adopting them. The increasing block tariff system is deemed as the most efficient in terns of inducing water saving behaviors while allowing for fair prices for necessary levels of consumption (see: Billings and Agthe (1980); Schefter and David (1985); Nieswiadomy and Molina (1989); Nieswiadomy (1992); Dandy et al. (1997); Winpenny (1994); Briscoe (1996); Hewitt and Hanemann (1995); Renwick and Green (2000); Liu et al. (2003); Olmstead et al. (2005)). Part of the literature is also interested in analyzing the determinant characteristics that can influence individual differences in consumption, when a similar tariff system is used.

The analysis on aggregate data allows an understanding of the effect of geographical, climate, socioeconomic regional characteristic and policy effects that would be possible at individual scale only for large, repeated in time, extremely expensive surveys. However, only a few studies in literature utilize aggregated data. These studies focus on price and income influence or on the impact of different drought management instruments.

The static panel data approaches focus on finding determinants of consumer choices and cross sectional aspect is prevalent in the analysis. Hoglund (1999) analyses 12 years water consumption in 282 Swedish towns. She applies several models for panel data (OLS, Fixed

Effect, Random Effect Between estimator, Random Effect – GLS and 2SLS) to a logarithmic demand function. The average price elasticity varies from -0.033 to –0.204.

Nauges and Thomas (2000b) analyse domestic consumption for 116 French towns managed by a single water utility in the period 1988-1993. The tariff structure is the same across towns but the price level varies on the basis of water cost of production and distribution. A logarithmic function is estimated using OLS, Fixed Effect, Random Effect and a Hausman-Taylor (1978), a Amemiya - MaCurdy (1986) and a Breush, Mizon and Schmidt (1989) Instrumental Variable Estimators. The average price elasticity is –0.215 in the preferred model (Breush, Mizon, Schmidt).

Martinez Espineira (2002) analyses a balanced panel of 122 towns of Northwest of Spain per 23 months. Towns are managed by different water utilities and tariffs applied differ for block size and marginal prices. Result estimates of a linear demand function using Fixed Effect and Random Effect – Between are compared to estimates from Instrumental Variable Estimators. Overall marginal price elasticities vary between –0.12 to –0.17.

Mazzanti and Montini (2006) are the first authors, as far as we know, to analyse panel data of water consumption in Italy. The dependent variable is the log of consumption per capita in 125 towns of Emilia Romagna in the period 1998-2001. The model is estimated using Fixed and Random Effect approaches. Average tariff elasticity varies from –0.99 to –1.33.

Other variables inserted in these studies are the income variable, the household size and the climatic variable. The coefficient of the income variable is expected to have a positive sign because of water is a normal good, as widely show in previous literature (Arbuès et al., 2004). The coefficient of the household size variable is expected to have a positive sign, because of large households are supposed to consume more than small ones. However, due to economies of scale in the use of water, the increase in water use is less than proportional to the increase in household size (Höglund, 1999; Nauges and Thomas, 2000b). Climatic variables are inserted in order to take in to account weather effect on both indoor and outdoor uses. The most used are temperature – which affected positively water consumption - and precipitation level – which is expected to affect negatively total consumption when outdoor uses are present (Nauges and Thomas (2000a); Moncur (1987); Corral (1998); etc.) and only a few of studies the evapotranspiration variable (Billings and Agthe (1980), Billings (1982), Agthe et al. (1986), Nieswiadomy and Molina (1988), and Hewitt and Hanemann (1995)). Only Dandy et al. (1997) used a water balance variable. Some other variable are sometimes inserted in water demand studies: a population age variable, frequency of billings and house size and age. Variables on population age are used because of young population is expected to have more requirement in water and act less carefully than older population. These expectations are confirmed by studies like Nauges and Thomas (2000b). The frequency of billings is inserted because of users who are more frequently billed might be expected to understand better the tariff structure and the relation between use and size of the bill. More billing periods would mean less water use (Stevens (1992); Nieswiadomy and Molina (1991); Martínez-Espiñeira (2002); Gaudin (2005)). Characteristics of houses are inserted because larger houses may be expected to require more water than small ones, while new buildings are expected to have more efficient infrastructures (taps, pipes etc.) than old ones (Nauges and Thomas (2000b)).

Another part of the literature is interested on drought management policies and tools. Mainly these studies analyse different impacts of price and non price instruments adopted during drought periods in order to reduce consumption. While price instruments reduce consumption through a tariff structure variation or a price variation, non price instruments operate through rationing quantity of water distributed or banning some outdoor uses.

Moncur (1987) is the first author to consider explicitly differences in consumer behaviour during drought and non drought periods. A water rationing dummy variable is inserted in the model to consider that water was distributed for a few hours per day only. This variable is significant and has the expected negative sign as the climate variable (the average rainfall). Corral et al. (1998) study the influence of price and non price instruments using a panel of aggregate data on three San Francisco Bay area towns. Martinez Espineira and Nauges (2004) deal with water rationing and outdoor use bans adopted in the city of Seville to control consumption in a drought period, while Renwick and Green (2000) analyse behaviour of household living in eight California Water Agencies. They show that public education campaigns are less efficient that mandatory policies such as water rationing, and that water rationing is more efficient if jointly used with an increase in price[2].

When we are interested to estimate temporal difference in consumption, we have to use a dynamic panel data approach. A limited number of works use a dynamic panel approach in order to analyse water demand, such as Hoglund (1999) and Nauges and Thomas (2000b). In these studies, lagged water consumption is a proxy for water use habits. Generally this approach has less explanatory power than the static one, in terms of policy implications. The use of temporal dummies captures the major part of the effect that would be explained by other variables.

Hoglund (1999) estimates a dynamic model based on a lagged consumption variable and level variables of all other covariates and using an instrumental variable approach already applied in water demand analysis by Carver and Boland (1980). She finds that consumers respond more to changes in average price of water than to marginal price changes. The long run price elasticity for the average price varies between -0.20 to –0.41.

Nauges and Thomas (2000a) use the dynamic panel approach to analyse a panel of 116 French municipalities for six year. They compared results obtained applying the Anderson - Hsiao (1982), the Arellano – Bond (1991) and the Holtz – Eakin (1988) GMM estimators. They find that households respond to a price increase in the long time period but not immediately. The long run elasticity is -0.56; the short term value varies between -0.10 to -0.30.

---

[2] More on this literature can be found on Terrebone, R. P., (2005).

3. Methodology

Data used have a balanced panel structure with N bigger than T. The equation to be estimated is assumed to be linear. All variables are transformed in logarithms. In the static approach it can be written as:

$$W_{it} = \beta X_{it} + \gamma Z_i + \alpha_i + \mu_{it} \qquad [1]$$

where *i* indexes individuals and *t* indexes time periods, W_{it} is the dependent variable, X_{it} is a 1 X K vector of time varying regressors (Cross Sectional Time Series variables, CS-TS forward) and Z_i is a 1 X G vector of time invariant regressors (Cross Sectional variables, CS forward). α_i is an individual specific and time invariant error component, assumed *iid* N (0, σ^2_α) and μ_{it} is a classical mean zero disturbance, *iid* N (0, σ^2_μ). β and γ are vectors of parameters associated with regressors. α_i is the component of variation not explained by the equation. That is, any factor that is specific to each town and that has not been included among the independent variables will be included in α_i and may be correlated with parts of X and Z. μ_{it} is assumed to be uncorrelated with both the explanatory variables and the effect α_i.

In our study, individuals are municipalities and *t* indicates the year of consumption. The dependent variable is the average annual consumption per household in Sardinia municipalities, CS- TS variables are average price, average income and the aridity index and CS variables are proportion of people over than 74 and a dummy that indicates tourist marine towns.

Static model can be estimated in various ways. Different models are based on different assumptions on individual heterogeneity.

The simplest model is the pooling model. It consists in an OLS estimation of model [1]. If we assume that α_i is identical for every town (so individual heterogeneity is all explained in regressors and in the usual error term), OLS estimation is unbiased and consistent. If heteroskedasticity is present, it is still possible to obtain a correct variance – covariance matrix, using white's correction. However, the estimates are inefficient as the errors are correlated within individuals.

OLS estimation does not allow analysing explicitly differences in cross sectional units. To do it, we can insert a dummy variable for each individual observation (Least Squared Dummy Variables) but such a model can be difficult to manage if N is quite large.

In that case, we have to use a panel specific estimator in order to take into account individual heterogeneity. If we assume that individual effect are fixed for each town, we can apply the within transformation. It consists in an estimation of that model taking all variables as deviation from individual (town) means. Model [1] can be rewritten as

$$W_{it} = \alpha_{i} + \beta X_{it} + \gamma Z_i + \mu_{it} \qquad [2]$$

where individual effect are indicated in the intercept which varies across all observations. This estimation is consistent and unbiased even if the independent variables are correlated with the individual error, but the Fixed Effect estimator drops out all time invariant regressors from the model.

However, time invariant variables can be important to explain an economic behaviour. In water demand literature, socio economic variables are generally not available as time series. In our work household size and dummy variable are time invariant. In order to maintain time invariant variables in the model a solution is to apply a Random Effect – GLS procedure. Model [1] can be rewritten as

$$W_{it} = \alpha + \beta X_{it} + \gamma Z_i + (\alpha_i + \mu_{it}) \qquad [3]$$

In this specification individual effects are random variables and individual heterogeneity is explained by error terms. The Random Effect model is efficient and consistent if there is no correlation between α_i and regressors. A Hausman test (1978) can be used to test for exogeneity of individual effects[3]. Rejection of the null hypothesis on no systematic differences between FE and RE estimator leads to reject RE.

A possibility to keep time invariant variable in the model in presence of endogeneity of regressor is to apply an instrumental variable estimator. In literature exist three approach: the Hausman – Taylor (HT, 1978), the Amemyia and MaCurdy (AM, 1986) and the Breush, Mizon and Schmidt approach (BMS, 1989). The last two estimators require stronger exogeneity assumption than HT. HT requires only that the means of the X_i variables be uncorrelated with the unobserved effect, α_i while AM and BMS requires that variables are not correlated at each point of time. Hausman – Taylor procedure uses the mean values and deviations from means of the assumed time-varying exogenous variables to (over)identify the parameters of the time invariant endogenous variables and construct instrumental variables. It consists in a two stage least squared regression of the group means of the residuals obtained from within regression on the setoff exogenous time – invariant variables. The HT estimator is at least as precise as the within estimator and may avoid the inconsistency of the GLS estimator. The AM estimator differs for using means values and deviations from means as T+1 instruments, separately for each of the T available time periods. Use of the HT and AM estimator requires identifying both endogenous and exogenous time invariant and time variant variables. The model to be estimated is

$$W_{it} = \beta_1 X_{1it} + \beta_2 X_{2it} + \gamma_1 Z_{1i} + \gamma_2 Z_{2i} + \alpha_i + \mu_{it} \qquad [4]$$

where X_{1it} e Z_{1i} are time variant and time invariant exogenous variables respectively and X_{2it} e Z_{1i} are time variant and time invariant endogenous variables respectively. We consider average income and average household size as endogenous variables, as explained before.

The model analysed can be estimated using another approach that takes more into account the temporal dimension of the panel data. Dynamic approach gives more importance to

---

[3] This test statistic is constructed as $M= q' \, cov(q)^{-1} q$ where $q = \beta_w - \beta_{GLS}$ and $cov(q) = cov\,\beta_w - cov\ \beta_{GLS}$. M is asymptotically distributed under H_0 as χ^2_K.. Significant differences in two vectors suggest miss-specification and the utilisation of within groups or instrumental variable techniques (Contoyannis and Rice, 2001).

temporal differences than individual ones. Dynamic approaches allow introducing lagged variables in estimations. Shortly, a dynamic model can be written as:

$$W_{it} = \beta W_{i,\,t-1} + \gamma AP_{it} + \delta X_{it} + \alpha_i + u_{it} \quad \text{where } u_{it} = \mu_i + \nu_{it} \qquad [5]$$

where *i* indexes individuals and *t* indexes time periods, W_{it} is the dependent variable and $W_{i,\,t-1}$ the one period lagged average consumption variable; AP_{it} is the actual average price and X_{it} is a vector of time varying regressors (income, water rationing and temporal dummies), u_{it} is an error term that is composed by μ_i that indicates the unobservable individual specific effect and ν_{it} that is the normal error term. Both are independently and identically distributed with zero mean and are not correlated ($E(\mu_i \ \nu_{it})=0$). X_{it} are supposed strictly exogenous respect to ν_{it} but it is allow that these variables can be correlated with the individual error term μ_i.

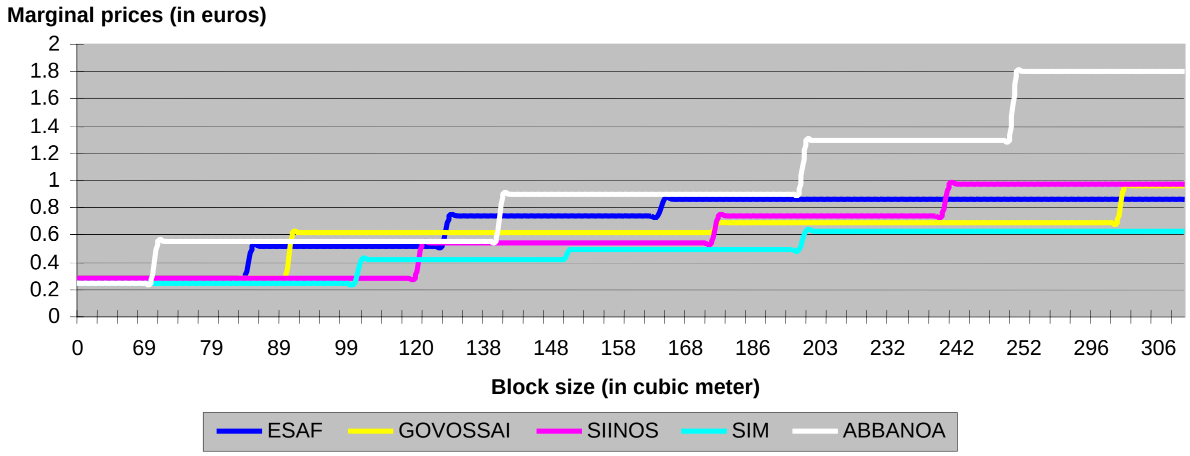
A range of estimators are designed starting from this base. The simplest one is the First difference approach proposed by Anderson and Hsiao. The dependent variable is expressed in first difference and its lagged value is uses as an instrument with other predetermined variables. First differencing the equation removes the individual effect, thus eliminating a potential source of omitted variable bias in estimation. However, differencing variables that are predetermined but not strictly exogenous makes them endogenous if the difference is correlated with the error difference. To correct them we use a GMM estimator as suggested by Holts-Eakin et alii (1988) and Arellano Bond (1991). In order to check for overidentification of restriction we have estimate also the Arellano –Bond two step estimator, based on a two step standard error correction.

4. Area of study

Like other Mediterranean regions, Sardinia is characterized by a water market in disequilibrium, the supply being often unable to meet the demand for industrial, residential, and agricultural uses. This is partly due to climatic reasons, but a large responsibility is also borne by a very inefficient management of the resource: water has been provided at political prices by a number of public agencies and utilities with often overlapping tasks, and no commitment to efficiency. Restricting our attention to the domestic sector only, there were 43 different utilities, each with a different increasing blocks tariff structure (i.e. different blocks and marginal prices), different prices for sewage and fixed costs, mostly unrelated to the actual cost of providing the service (see table 1 in Appendix). The consequence was that there was not enough money to invest in new infrastructure (or just replace old pipes), and the percentage of water losses was as high as 60% in 2001 (RAS, Piano d'Ambito della Regione Sardegna).

In 2004 the Regional Government finally executed the reform process in the water sector promoted by the national law 36/1994. One of the fundamental acts in the reform process was the institution of a unique water agency for the whole regional area, and the application of a unique tariff system, designed to cover variable costs, and to penalize excessive use of the resource. The tariff is now structured with smaller blocks and higher marginal prices than they used to be –especially for high levels of consumptions. The actual tariff (see the figure below) is composed by five blocks rather than four in order to take into account more for highest level of consumption. Marginal prices linked to latest blocks are quite higher than marginal prices applied by previous water utilities until 2004. Moreover marginal prices of the two lower blocks are not much higher than previous prices in order to avoid penalizing large households, as can happen using and increasing block tariff system (Bar Shira et al. (2005); Liu et al. (2003)). The more recent update of the tariff system (November 2006) has introduced lower prices for large households with low consumption.

Fig. 1. Marginal prices per block



Furthermore, reform of 2005 introduces a different (higher) tariff for non residents and for low income residents (table 2). After the first year, it seems that the new tariff policy has quite succeeded in inducing some reduction in the average consumption of water. As clearly shown in figure 2, 2005 average aggregated consumption are more concentrated in lower consumption classes than in previous years. Yet, domestic consumption in the region is still higher than the Italian average (100 annual cubic meters with respect to 85 cubic meters[4]), although there are differences across towns which might be explained by socio-economic, climatic, geographical characteristics (see table 3).

In the years 1998-2003 Sardinia has experienced a drought period. In order to keep the level of supplies under control, some restrictions have been imposed in the water service, namely the service was interrupted for several hours on a daily basis (see table 4). The actual level of shortages was different across towns, depending on the specific hydrological sub-system they belong to.

Sardinia is widely recognized as an important sea tourist site in Europe. Official data (ISTAT, 2005) indicates that 10.203.401 tourist stayed in Sardinia in registered structures, prevalently in sea side towns and areas. This is an extremely high number if compared to the official population of Sardinia, which is composed of approximately of 1.600.000 inhabitants.

---

[4] Data source: RSA (2006), Piano Generale degli Acquedotti; Federgasacqua (2005)

Moreover, this number does not show the real size of the tourist phenomenon. On the basis of ISTAT (2007) "Survey of holidays and travel in Italy" made in 2004, CRENoS (2007) shows that 34.514.000 tourist spend at least a night in Sardinia. The 79% of total number of tourist stayed in secondary houses. As already suggested by Martinez Espineira (2003) for the Spain, we can hypothesize that this high number of people has a great impact on domestic water distribution and consumption even if the permanence is related only to the summer period.

5. Data

The balanced panel dataset used for estimations is composed by 240 individual observations (towns) over six years (2000 - 2005). Data concerning domestic water consumption, prices, number of users was directly collected by water utilities. Four utilities accepted to collaborate to our research: ESAF (Ente Sardo Acquedotti e Fognatura) which managed 220 of towns in the dataset, Consorzio di Bonifica del Govossai which managed 18 towns, SIM and SIINOS which was the Water Utility of the City of Cagliari and the City of Sassari respectively. The ESAF, Consorzio di Bonifica del Govossai and SIM were public utilities, but SIINOS was a private utility. All utilities now have been merged in a unique water utility, Abbanoa.

The information on water rationing was obtained by the water utilities and the Water Management Department of the Regional Government. Socioeconomic variables are collected from National Census Survey made by ISTAT (National Institute of Statistic). Income data is collected by Treasury Ministry and are available in the website. Climatic data is given by SAR (Regional Department for Climate and Agricultural data). Data on tourism are obtained from the "Regional Plan for Sustainable Tourism" (RAS) and from the "Annual Report of Sardinian Economy – 14th Edition" (CRENoS).

Descriptive statistics on the data are available in the appendix (tables 5, 6 and 7).

Dependent Variable

The dependent variable is annual average consumption (AVCONS) per user per town. Data are collected over 2000 to 2005 and expressed in cubic meters. This variable has been constructed dividing total consumption per year per town by users per year per town. All data concerns domestic users.

Time Variant Variables

Time series cross sectional variables are:

- Annual average price variable (AP) expressed in euros per year per user. It is calculated ex post as the ratio of the total amount billed over the total consumption in a town. We use the average price because of household are more responsive to average than marginal or other price variables. This is a common result in literature when block tariff system are used.

- Annual income variable per tax payer (INCOME), expressed in thousand of euros per tax payer per town. It is calculated as the ratio of income declared by all workers in a town over the total number of tax payers per town. Data comes from Treasury Ministry web site. As proposed by Nordin and Taylor, a Difference variable is added to Income, It has been calculated as what users have been paid if all quantity was billed at marginal price minus the total bill paid.
- The climate variable. The aridity index (AI) is calculated as the ratio between the yearly average precipitation (expressed in millimetres) and the yearly average evapotranspiration[5] (expressed in millimetres). The adopted formulation has been proposed by UNEP in order to classify areas on the basis of climatic condition. Differences in the index value between towns are due to difference in altitude and in distance from the sea. No previous studies in water management literature use aridity index. The aridity index permits to consider influence of climate interaction (i.e. interaction between temperatures, humidity and precipitation) on both indoor and outdoor uses.
- Water rationing variable (WATRAT). During 2000 – 2003 drought water was rationed in all towns in the Region. Water from utilities was available for a few hours per day only. This variable is calculated on the basis of Regional Laws on water management during drought and water utilities information. We have constructed this variable as the percentage of hours of water shortages in a year over the total amount of hours in a year. In that way we can consider changes of hours of rationing over a year. That variable was not used previous in literature - even if a similar one can be found in Espineira and Nauges (2004) - and this can be an improvement with respect to dummies or categorical variables that have been used in previous literature.
- Water utilities dummies variables (ESAF, Govossai, SIINOS and SIM). These four variables vary between municipalities and years, because of all municipalities have the same water utility manager, Abbanoa, in 2005. These dummies take into account for differences in management practices - such as frequency of billings - that can influence the consumers' behaviour (Gaudin, 2005). ESAF was the most important water utility because of it managed the majority of Sardinian municipalities, so we consider it as the benchmark dummy.

Time Invariant Variable

- Average size of households in town (HOUSIZE), which indicates the average number of people in households. Previous descriptive analysis showed a positive correlation with:

---

[5] Evapotranspiration (ET) is the sum of evaporation and plant transpiration. In our study we use the Potential Evapotranspiration (ET0). Potential evapotranspiration is a representation of the environmental demand for evapotranspiration and represents the evapotranspiration rate of a short green crop, completely shading the ground, of uniform height and with adequate water status in the soil profile. Atmospheric factors such as temperature, humidity and wind affect transpiration.

a. size of town; b. percentage of young people; c. percentage of houses built after 1991. Also this variable is negatively correlated with: a. the surface of houses: b. the percentage of old people. The existence of all these correlation leads us not to insert variable on age of population and houses in econometric model.

- A dummy that indicates tourist marine towns (TOUR). This variable is used to verify if a high presence of tourists in secondary residence during summer months can influence annual water consumption. We have considered towns that have a number of bed accommodations higher than the average regional value as tourist towns. Average regional value take in account both official data (collected by ISTAT, 2004) on hotels, residences, bed&breakfasts and camping and estimated data on bed accommodation on secondary residence rent in the summer (collected and estimated for the Regional Plan for Sustainable Tourism, 2006). The 14% of the towns in the database are tourist towns. All tourist towns are marine towns.

Time Variant Variables

- Time dummy variables. All municipalities have the same utility manager (Abbanoa) in 2005. So we have to make a temporal comparison between years, in order to determine the effect of the change in tariff system and prices and actual management practices with the previous one. Moreover, these dummies take into account all the time differences that we are not able to control with other variables. If the reform induces a real decrease in consumption we expect to have a negative coefficient. This means that there has been a decrease in consumption respect to previous years. Because of water rationing measures was applied in the period over 2000 to 2003, we consider 2004 as the benchmark.

6. Results

The estimation results are showed in table 8[6] and 9. The model used is

$$\mathrm{Log}\ (W_{it}) = \alpha + \beta \log(AP_{it}) + \gamma \log(INCOME_{it}) + \delta \log(HOUSIZE_{i}) + \eta\,(AI_{it}) + \varepsilon\,(WATRAT_{it}) + \theta\,(TOUR_{i}) + \iota(GOVOSSAI_{it}) + \iota(SIINOS_{it}) + \iota(SIM_{it}) + u_{it} \quad \text{where } u_{it} = \mu_{i} + \nu_{it} \qquad [6]$$

We start our analysis with the simplest model for static panel data, i.e. the pooling OLS. All coefficients are significant and have the expected signs. We can find similar results with the RE – GLS model, but water utilities variables coefficient lose significance. The FE model shows us stronger differences in results. The intercept and the water utilities variables are not significant. A Hausman test was used to test for the presence of correlation between unobserved heterogeneity and regressors in RE model. The Hausman test compares FE and RE results. Chi squared value at 5% level of confidence is lower than the test value so we have to reject the exogeneity assumption. In order to correct for the endogeneity, we adopt the

---

[6] The software used is STATA 9.2. S.E.

Hausman – Taylor and the Amemiya e MaCurdy instrumental variable estimators. These estimators allow us to obtain consistent results and to keep in the model cross section variables. Because of the possibility to have simultaneity problem, we consider the average price as an endogenous covariate. The climate variable that can be correlated to geographical characteristics of municipalities is also considered endogenous.

The Hausman test is used to compare HT and AM with FE results in order to check for the absence of correlation between regressors and unobserved heterogeneity. The test confirms that the instrumental variable estimators adjust for endogeneity so to consider the average price variable and the climate variables as the endogenous variable has been correct.

We obtain closer coefficient values between the HT and AM instrumental variable estimators as expected. Generally FE is considered the benchmark model (Greene, 2003). It is expected to obtain coefficient values similar to the FE model when Instrumental Variable Estimators have been used to correct for the biased of RE –GLS. Indeed, water utilities variables are not significant as in FE model. The preferred model is the HT instrumental variable model, because of the low value of the Hausman test indicates that that model is able to better correct for the endogeneity problem.

The average price variable is highly significant and with the expected sign in all models. The elasticity value in the HT model is -0.224. These results are not different from previous results in literature that use the average price variable [Arbuès et al. (2003)] and are similar to those found by Nauges and Thomas (2000) using average price. Corral et al. (1998) showed strictly lower value for price elasticity measured in a drought period.

The income variable shows the correct sign and it is significant in all models with a coefficient close to that estimated by Mazzanti and Montini (2006) with the same source of data for income.

The coefficient of average household size variable is quite high level significant: in the preferred model the coefficient value is 1.278. The coefficient value is larger than what found in previous literature (Nauges e Thomas (2000), the Martinez Espineira (2002) instrumental variable results and Mazzanti e Montini (2005)), indicating that consumption increases more than proportionally after an increase in the household size. An opposite result is generally found in literature (Hoglund (1999)). This result requires further analysis, to explore if other factors, correlated to this variable, are at work.

The aridity index variable is significant and has the expected sign. It means that higher evapotranspiration and lower precipitation levels lead to higher level of consumption. This result is important because of this variable taking into account for the complexity of the interaction between single weather variables (such as temperature, humidity rate, wind influence etc.) can explain impact of climate both on indoor and outdoor uses. Moreover, it represents a good improvement respect to the climate partial analysis of previous literature.

Water rationing variables shows the expected sign and is significant. The coefficient value is slightly lower than the value found by Espineira e Nauges (2004) using a similar variable on

City of Sevilla. No other comparison can be made because of all the other previous studies use a dummy or categorical variable.

As supposed, the tourist marine town dummy variable has the expected sign and it is quite significant in all models. In the preferred one the coefficient value is 0.154. This means that tourist towns have higher consumption than similar no tourist towns. Since we have analysed only domestic consumption, this is a proof that summer tourists staying in secondary residences have a strong impact on domestic consumption. As indicated before, this result can be explained considering that in some case the tourist population is a multiple of the resident population.

GOVOSSAI and SIINOS water utilities dummy variables are not significant in the preferred models. It means that there were not differences in management practices that can explain difference in consumption. Moreover, we can note that Govossai has a positive coefficient - so their consumption was higher than ESAF - and SIINOS a negative coefficient. SIM water utility dummy variable is significant and has a positive coefficient. Analysing the coefficient value we can verify that SIM average consumption level is quite higher than ESAF average consumption level. ESAF consumption level is conditioned by the fact that all tourist towns in database were managed by it. Consider that, we can conclude that SIM past level of consumption has been influenced by lower previous marginal prices and proper management practices applied by SIM (see figure 1).

Finally some short comments on the dynamic estimation. The used model is

$$\mathrm{Log}\ (W_{it}) = \beta \log(AP_{it}) + \gamma \log(INCOME_{it}) + \delta\,(WATRAT_{it}) + \eta(\mathrm{Year}\ 2001) + \varepsilon(\mathrm{Year}\ 2002) + \theta\,(\mathrm{Year}\ 2003) + \iota(\mathrm{Year}\ 2005) + u_{it} \quad \text{where } u_{it} = \mu_i + \nu_{it} \qquad [7]$$

A pooling OLS with lagged consumption variable and time dummy variables and a FE model were estimated in order to confirm of the importance of the temporal dummies. The significance of the dummies indicates that a dynamic approach is suitable (Manera and Galeotti, 2005). The dummies inserted are significant – with the exception of the 2003 - and with the expected sign. The benchmarking year is 2004, because there was no water shortages and the new reform were not yet in force. Considering that an endogeneity problem can arise, we apply an Arellano – Bond estimator. The estimated model leads to use all lag periods available. Both Arellano – Bond one step and two step estimators are consistent because of the absence of autocorrelation of second order. The Arellano – Bond one step estimator is the preferred model. In all models the dummy variable that indicates the year 2005 is quite significant and with a negative coefficient. Moreover the coefficient value is very small and reflects the small decrease in average consumption (130 cubic meter in 2005 respect to 139 in 2004) even if we can observe a general shift of municipal consumption towards lower consumption level, as shown in figure 2 in the Appendix. Moreover this result indicates that the entry into force of the water reform and of the increase of price has coincided with a decrease in domestic water consumption with respect to the benchmarking year. In the preferred model, in 2003 there was higher consumption than 2004: this result can be due probably to the effect of the end of the period of water shortage. Even if it is no significant, the water rationing variable has been inserted in order to take into account for the part of consumption reduction due to the restriction in quantity.

Lagged consumption value is significant and has a high coefficient value (-0.2077) in the preferred model. The price level shows a significant and negative coefficient but a lower value of the elasticity than in the static estimation.

7. Conclusions

The aim of our work was to analyze the determinants of water demand, and to see how the new water tariff water introduced in Sardinia is effective in controlling excessive consumption.

The price elasticity of demand estimated is in line with other estimates based on panel data found in previous literature. Its level (about 0.2) would not induce to consider price as an effective tool to control demand; however, further research will be carried out to analyze with better suited econometric instruments (Maximum Likelihood) the demand function in presence of a kinked budget constraint.

Our results show that municipalities characterized by higher levels of income have higher levels of consumption of water than poorer municipalities. The tariff system now in force works as an incentive for low income households to consume water responsibly, since only in this case they will enjoy a reduction in the tariff. The tourist dummy variable clearly demonstrates that non residents have a great impact on the average consumption of Sardinian municipalities. This warrants the adoption of differentiated tariffs for secondary houses, which are often used as tourist accommodations, so that the impact of tourist demand on the resource can be properly taken into account: also bearing in mind that coastal areas have higher aridity index rates than the interior part of the island.

Large households have higher levels of consumption: while this is a logical result, yet the level of the coefficient implies a high elasticity, which is not confirmed in the literature: further analysis is required to shed more light on this issue.

The significant effect of the climate variable on the demand of water might be related to outdoor consumption: unfortunately we do not have information on private gardens in towns. It may be useful to analyze future trends in dwelling preferences: if more people will choose suburban, independent houses with private gardens, this may have a strong impact on the demand of domestic water.

The entry into force of the new tariff system has coincided with some reduction in consumption, and an overall change in the consumption distribution (cf. Fig. 2). Unfortunately at this stage we are not able to check if this reduction is only a temporary effect due to a response to the “price increase announce” effect after the new management has been introduced. Further analyses in the next years will provide useful information on this issue.

Reference

Agthe, D.E., Billings, R.B., Dobra, J.L., Rafiee, K., (1986). A simultaneous equation demand model for block rates. Water Resources Research 22 (1), 1–4.

Arbues, F., Barberan, R., Villanua, I., (2004). Price impact on urban residential water demand: a dynamic panel data approach. Water Resource Research, vol. 40, W11402.

Arbues, F., Martınez-Espiñeira, R., García-Valiñas M. A., (2003). Estimation of Residential Water Demand: A State of the Art Review. Journal of Socio-Economics, Vol 32, No 1, 81-102.

Bar Shira Z., Cohen N., Kislev Y., (2005). Residential demand for water in Israel. Working Paper Department of Agricultural Economics and Management, Hebrew University, Rehovot, Israel.

Billings, R.B., (1982). Specification of block rate price variables in demand models. Land Economics 58 (3), 386–393.

Billings, R.B., Agthe, D.E., (1980). Price elasticities for water: a case of increasing block rates. Land Economics 56 (1), 73–84.

Briscoe, J., (1996). Water as an economic good: the idea and what it means in practice. Paper presented at the World Congress of the International Commission on Irrigation and Drainage. September, Cairo

Bond, S. (2002). Dynamic panel data models: A guide to micro data methods and practice. Working Paper 09/02. Institute for Fiscal Studies, London.

Carver, P.H., Boland, J.J., (1980). Short-run and long-run effects of price on municipal water use. Water Resources Research 16 (4), 609–616.

Contoyannis P., Rice N. (2001). The impact of health on wages: evidence from the British Household Panel Survey, Empirical Economics, 26(4): 599-622.

Corral, L., Fisher, A.C., Hatch, N., (1998). Price and non-price influences on water conservation: an econometric model of aggregate demand under nonlinear budget constraint. Working Paper No. 881, Department of Agricultural and Resource Economics and Policy, University of California at Berkeley.

Dandy, G., Nguyen, T., Davies, C., 1997. Estimating residential water demand in the presence of free allowances. Land Economics 73 (1), 125–139.

Hewitt, J.A., Hanemann, W.M., 1995. A discrete/continuous choice approach to residential water demand under block rate pricing. Land Economics 71 (2), 173–192

Höglund, L., (1999). Household demand for water in Sweden with implications of a potential tax on water use. Water Resources Research 35 (12), 3853–3863.

Gaudin, S. (2005). Using water bills to reinforce price signals: evidence from the US. IWA International Conference on Water Economics, Statistics, and Finance Rethymno, Greece, 8-10 July 2005

Greene (2003). Econometric Analysis, Prentice Hall.

Hrovatin and Bailey (2001). Implementing the European Commission’s water pricing communication: cross-country perspectives. Utilities Policy 10 (2001) 13–24

Kent M., Newnham R., Essex S. (2002). Tourism and sustainable water supply in Mallorca: a geographical analysis. Applied Geography 22, pp. 351 – 374

Lindberg K., McCool S., Stankey G., (1997). Rethinking Carrying Capacity. Annals of Tourism Research, Volume 24, Number 2, 1997 , pp. 461-465(5)

Liu, J., Savenije, H. H.G., Xu, J. (2003). Water as an economic good and water tariff design. Comparison between IBT-con and IRT-cap. Physics and Chemistry of the Earth 28, 209–217

Manera M., Galeotti M. (2005). Microeconometria. Metodi e Applicazioni, Carocci Editore, Roma

Martınez-Espiñeira, R., (2002). Residential water demand in the Northwest of Spain. Environmental and Resource Economics 21 (2), 161–187.

Martınez-Espiñeira, R., Nauges, C., (2004). Is all domestic water consumption sensitive to price control. Applied Economics, 36, 1697–1703

Mazzanti, M., Montini, A., (2006). The Determinants of Residential Water Demand. Applied Economics Letters, 13, pp.107-111

Moncur, J., (1987). Urban water pricing and drought management. Water Resources Research 23 (3), 393–398.

Nauges, C., Thomas, A., (2000a). Dynamique de la consommation d'eau potable des ménages: une étude sur un panel de communes françaises. Economie & Prevision, numéro 143 -144, avril – juin, 2000/2-3

Nauges, C., Thomas, A., (2000b). Privately-operated water utilities, municipal price negotiation, and estimation of residential water demand: the case of France. Land Economics 76 (1), 68–85

Nauges, C., Thomas, A., (2003). Long – run study of residential water consumption. Environmental and Resource Economics. 26 : 25-43.

Nieswiadomy, M.L., (1992). Estimating urban residential demand: effects of price structure, conservation and education. Water Resources Research 28 (3), 609–615.

Nieswiadomy,M.L., Molina, D.J., (1988). Urban water demand estimates under increasing block rates. Growth and Change 19 (1), 1–12.

Nieswiadomy, M.L., Molina, D.J., (1989). Comparing residential water estimates under decreasing and increasing block rates using household data. Land Economics 65 (3), 280–289.

Nieswiadomy, M.L., Molina, D.J., (1991). A note on price perception in water demand models. Land Economics 67 (3), 352–359.

Olmstead, S. M., Hanemann W. M., Stavins R. N. (2005). Do Consumers React to the Shape of Supply? Water Demand under Heterogeneous Price Structures. Discussion Paper 05–29, Resource For the Future, Washington D.C.

Olsen, M.A., (2001). The new water framework directive for the European Union and its possible effects on the Mediterranean insular context - Prospects for a sustainable water policy of the Balearic Islands for the coming decades. International Conference "L'aigua i la seva gestiò. Perspectives de futur", Balearic Islands, 1/2 February 2001

Regione Autonoma della Sardegna (2005), Piano d'Ambito della Regione Sardegna.

Regione Autonoma della Sardegna (2005), Piano Regionale per il Turismo Sostenibile (forthcoming).

Renwick, M.E., Archibald, S.O., 1998. Demand side management policies for residential water use: who bears the conservation burden? Land Economics 74 (3), 343–359.

Renwick, M.E., Green, R., (2000). Do residential water demand side management policies measure up? An analysis of eight California water agencies. Journal of Environmental Economics and Management 40 (1), 37–55.

Schefter, J.E., David, E.L., (1985). Estimating residential water demand under multi-tariffs using aggregate data. Land Economics 61 (3), 272–280.

Terrebone, R. P., (2005). Residential water demand management programs: a selected review of the literature. Water Policy Working Paper #2005-002

Winpenny, J. (1994). Managing water as an economic good. Routledge London.

Wooldridge (2002), Econometric of Cross Section and Panel Data, MIT Press.

Appendix

CASE STUDY DESCRIPTION

Table 1. Water Rationing Measures over 2000 to 2005

Municipalities involved	Hours regular water distribution (% by year)					
ESAF	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
All municipalities	50%	42%	26%	71%	100%	100%
CONSORZIO DI BONIFICA DEL GOVOSSAI	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Nuoro	100%	100%	52%	52%	85%	100%
Sarule, Orani, Oniferi	100%	100%	84%	52%	75%	75%
Orotelli	100%	100%	84%	52%	75%	88%
Ottana	100%	100%	84%	72%	100%	100%
Dorgali	100%	100%	100%	92%	100%	100%
Orgosolo	100%	100%	55%	40%	97%	100%
SIINOS	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Sassari	50%	42%	26%	71%	81%	81%
SIM	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Cagliari	50%	42%	26%	71%	81%	81%

<table>
<tr><th colspan="7">Table 2. Tariff systems and price levels in 2000, 2001, 2002, 2003 and 2004</th></tr>
<tr><th>Block size (in cubic meters)</th><th colspan="6">Marginal Prices (in euros)</th></tr>
<tr><th>ESAF</th><th>2000</th><th>2001</th><th colspan="2">2002[A]</th><th>2003</th><th>2004</th></tr>
<tr><td>0 – 84</td><td>0.25</td><td>0.25</td><td colspan="2">0.28</td><td>0.295</td><td>0.295</td></tr>
<tr><td>85 – 124</td><td>0.45</td><td>0.45</td><td colspan="2">0.49</td><td>0.517</td><td>0.517</td></tr>
<tr><td>125 – 164</td><td>0.64</td><td>0.64</td><td colspan="2">0.695</td><td>0.738</td><td>0.738</td></tr>
<tr><td>More than 165</td><td>0.76</td><td>0.76</td><td colspan="2">0.825</td><td>0.886</td><td>0.886</td></tr>
<tr><th>CONSORZIO DI BONIFICA DEL GOVOSSAI</th><th>2000</th><th>2001</th><th>Block size in cm</th><th>2002[B]</th><th>2003[C]</th><th>2004[D]</th></tr>
<tr><td>0 – 90</td><td>0.21</td><td>0.21</td><td>0 – 60</td><td>0.22</td><td>0.26</td><td>0.28</td></tr>
<tr><td>91 – 180</td><td>0.47</td><td>0.47</td><td>61 – 120</td><td>0.51</td><td>0.57</td><td>0.62</td></tr>
<tr><td>181 – 300</td><td>0.53</td><td>0.53</td><td>121 – 200</td><td>0.54</td><td>0.63</td><td>0.69</td></tr>
<tr><td>More than 300</td><td>0.71</td><td>0.71</td><td>More than 200</td><td>0.67</td><td>0.85</td><td>0.96</td></tr>
<tr><th>SIINOS</th><th>2000</th><th>2001</th><th colspan="2">2002</th><th>2003</th><th>2004</th></tr>
<tr><td>0 – 120</td><td>0,276</td><td>0,290</td><td colspan="2">0,290</td><td>0,290</td><td>0,290</td></tr>
<tr><td>121 – 180</td><td>0,516</td><td>0,542</td><td colspan="2">0,542</td><td>0,542</td><td>0,542</td></tr>
<tr><td>181 – 240</td><td>0,705</td><td>0,740</td><td colspan="2">0,740</td><td>0,740</td><td>0,740</td></tr>
<tr><td>More than 240</td><td>0,930</td><td>0,976</td><td colspan="2">0,976</td><td>0,976</td><td>0,976</td></tr>
<tr><th>SIM</th><th>2000</th><th>2001</th><th colspan="2">2002</th><th>2003</th><th>2004</th></tr>
<tr><td>0 – 100</td><td>0.25</td><td>0.25</td><td colspan="2">0.25</td><td>0.25</td><td>0.25</td></tr>
<tr><td>101 – 150</td><td>0.42</td><td>0.42</td><td colspan="2">0.42</td><td>0.42</td><td>0.42</td></tr>
</table>

151 – 200	0.51	0.51	0.50	0.50	0.50
More than 200	0.63	0.63	0.63	0.63	0.63

A) values reported are a mean of different prices applied in 2002 B), C), D) values reported are means of different prices applied

Table 3. ABBANOA – Tariff System and price level in 2005

Block size in cubic meters	Marginal Price
Residential Domestic Pricing	
0 – 70	0.25
71 – 140	0.55
141 – 200	0.90
201 – 250	1.30
More than 250	1.80
Non residential Domestic Pricing	
0 – 140	0.55
141 – 200	0.90
201 – 250	1.30
More than 250	1.80
Residential Domestic Pricing – Low Income Household	
0 – 70	0.1250
71 – 140	0.2750
141 – 200	0.90
201 – 250	1.30
More than 250	1.80

Table 4. Average Consumption over 2000 to 2005

Average Consumption per capita (cubic meters)	Distribution of Municipalities by class of consumption (%)					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Less of 100	82.5	5.4	15.8	8.3	13.8	20.0
between 101 and 150	12.1	48.3	56.7	59.6	54.2	56.7
between 151 and 200	3.3	34.6	22.5	24.2	24.6	17.9
More than 200	2.1	11.7	5.0	7.9	7.5	5.4

Variables summary

Table 5. Description of variables

```
   Variable |      Description of variables
------------+--------------------------------------------------------
     AVCONS |  water annual consumption per household – CS-TS (cubic meters)
         AP |  average price – CS-TS (euros)
     INCOME |  income per capita – CS-TS (euros)
    HOUSIZE |  household average size – CS
         AI |  aridity index – CS-TS(mm)
       WRAT |  percentage of hours of water shortages – CS-TS hours per year
       TOUR |  marine tourist town – CS (dummy)
       ESAF |  ESAF water utility – CS and TS(dummy)
   GOVOSSAI |  GOVOSSAI water utility – CS and TS(dummy)
     SIINOS |  SIINOS water utility – CS and TS(dummy)
        SIM |  SIM water utility – CS and TS(dummy)
     Y_2000 | yearly dummy variable - TS(dummy)
     Y_2001 | yearly dummy variable - TS(dummy)
     Y_2002 | yearly dummy variable - TS(dummy)
     Y_2003 | yearly dummy variable - TS(dummy)
     Y_2004 | yearly dummy variable - TS(dummy)
     Y_2005 | yearly dummy variable - TS(dummy)
------------+--------------------------------------------------------
```

Table 6. Descriptive statistics on the sample – NT data observations

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
      AVCONS |      1440     130.082    49.13369   16.13778   554.4247
          AP |      1440     1.06197    .9573543   .0037903   31.81017
      INCOME |      1440     9516.37      2549.2   654.1812   22701.08
     HOUSIZE |      1440    2.749458     .234197       2.08       3.33
          AI |      1440     .483004    .1798552   .0861722   1.096786
-------------+--------------------------------------------------------
        WRAT |      1440    .6725417    .2802921        .27          1
        TOUR |      1440    .1458333    .3530617          0          1
        ESAF |      1440    .7638889    .4248388          0          1
    GOVOSSAI |      1440       .0625    .2421456          0          1
      SIINOS |      1440    .0034722    .0588436          0          1
         SIM |      1440    .0034722    .0588436          0          1
-------------+--------------------------------------------------------
      Y_2000 |      1440    .1666667    .3728075          0          1
      Y_2001 |      1440    .1666667    .3728075          0          1
      Y_2002 |      1440    .1666667    .3728075          0          1
      Y_2003 |      1440    .1666667    .3728075          0          1
      Y_2004 |      1440    .1666667    .3728075          0          1
-------------+--------------------------------------------------------
      Y_2005 |      1440    .1666667    .3728075          0          1
```

Table 7. Descriptive statistics on the sample – NT, N and T data observations

```
Variable         |      Mean   Std. Dev.       Min        Max |    Observations
-----------------+--------------------------------------------+----------------
AVCONS   overall |   130.082   49.13369   16.13778   554.4247 |     N =    1440
         between |             35.67272   58.14164   287.1582 |     n =     240
         within  |             33.85259  -129.0654    503.033 |     T =       6
                 |                                            |
AP       overall |   1.06197   .9573543   .0037903   31.81017 |     N =    1440
         between |             .4278382   .3917429   6.378219 |     n =     240
         within  |             .8568067  -4.333578   26.49392 |     T =       6
                 |                                            |
INCOME   overall |   9516.37     2549.2   654.1812   22701.08 |     N =    1440
         between |             2205.399   4234.573   19633.61 |     n =     240
         within  |             1285.121    4231.43   13269.59 |     T =       6
                 |                                            |
HOUSIZE  overall |  2.749458    .234197       2.08       3.33 |     N =    1440
         between |             .2346049       2.08       3.33 |     n =     240
         within  |                    0   2.749458   2.749458 |     T =       6
                 |                                            |
AI       overall |   .483004   .1798552   .0861722   1.096786 |     N =    1440
         between |             .0625368   .3605066    .663171 |     n =     240
         within  |             .1686731   .0003261   .9294109 |     T =       6
                 |                                            |
WRAT     overall |  .6725417   .2802921        .27          1 |     N =    1440
         between |             .0777201   .5883333          1 |     n =     240
         within  |             .2693403   .2892083   1.020875 |     T =       6
                 |                                            |
TOUR     overall |  .1458333   .3530617          0          1 |     N =    1440
         between |             .3536766          0          1 |     n =     240
         within  |                    0   .1458333   .1458333 |     T =       6
                 |                                            |
GOVOSSAI overall |     .0625   .2421456          0          1 |     N =    1440
         between |             .2199515          0   .8333333 |     n =     240
         within  |             .1020975  -.7708333   .2291667 |     T =       6
                 |                                            |
SIINOS   overall |  .0034722   .0588436          0          1 |     N =    1440
         between |             .0537914          0   .8333333 |     n =     240
         within  |             .0240646  -.8298611   .1701389 |     T =       6
                 |                                            |
SIM      overall |  .0034722   .0588436          0          1 |     N =    1440
         between |             .0537914          0   .8333333 |     n =     240
         within  |             .0240646  -.8298611   .1701389 |     T =       6
                 |                                            |
ESAF     overall |  .7638889   .4248388          0          1 |     N =    1440
         between |             .2308025          0   .8333333 |     n =     240
         within  |              .356936  -.0694444   .9305556 |     T =       6

Y_2000   overall |  .1666667   .3728075          0          1 |     N =    1440
         between |                    0   .1666667   .1666667 |     n =     240
         within  |             .3728075          0          1 |     T =       6
                 |                                            |
Y_2001   overall |  .1666667   .3728075          0          1 |     N =    1440
         between |                    0   .1666667   .1666667 |     n =     240
         within  |             .3728075          0          1 |     T =       6
                 |                                            |
Y_2002   overall |  .1666667   .3728075          0          1 |     N =    1440
         between |                    0   .1666667   .1666667 |     n =     240
         within  |             .3728075          0          1 |     T =       6
                 |                                            |
Y_2003   overall |  .1666667   .3728075          0          1 |     N =    1440
         between |                    0   .1666667   .1666667 |     n =     240
         within  |             .3728075          0          1 |     T =       6
                 |                                            |
Y_2004   overall |  .1666667   .3728075          0          1 |     N =    1440
         between |                    0   .1666667   .1666667 |     n =     240
         within  |             .3728075          0          1 |     T =       6
                 |                                            |
Y_2005   overall |  .1666667   .3728075          0          1 |     N =    1440
         between |                    0   .1666667   .1666667 |     n =     240
         within  |             .3728075          0          1 |     T =       6
                 |                                            |
```

Estimation results

Table 8. Estimation Results – Static Panel Approach

	OLS	FE	RE - GLS	HT (PME and AI endogenous)	AM (PME and AI endogenous)
INTERCEPT	-0.606	0.004	-0.824	-0.713	-0.715
	(-2.00)**	(0.01)	(-2.26)**	(1.79)*	(1.80)*
AP	-0.202	-0.219	-0.214	-0.224	-0.224
	(-7.70)***	(-8.08)***	(-8.55)***	(-8.79)***	(-8.76)***
INCOME	0.433	0.499	0.453	0.431	0.431
	(11.78)***	(6.92)***	(10.29)***	(9.02)***	(9.03)***
HOUSIZE	1.210	-	1.226	1.278	1.277
	(11.93)***		(9.15)***	(8.26)***	(8.25)***
AI	0.521	0.698	0.618	0.723	0.721
	(10.08)***	(12.07)***	(12.39)***	(14.16)***	(14.14)***
WATRAT	-0.086	-0.158	-0.116	-0.134	-0.134
	(-2.49)**	(-4.77)***	(-3.65)***	(-4.31)***	(-4.31)***
TOUR	0.153	-	0.148	0.154	0.154
	(6.18)***		(4.54)***	(4.07)***	(4.06)***
GOVOSSAI	0.113	-0.0021	0.094	0.076	0.077
	(2.63)***	(-0.01)	(2.03)**	(1.57)	(1.58)
SIINOS	-0.324	0.218	-0.243	-0.183	-0.182
	(-2.31)**	(0.75)	(-1.43)	(-0.99)	(-0.99)
SIM	0.570	0.055	0.477	0.439	0.438
	(4.07)***	(0.19)	(2.84)***	(2.37)**	(2.37)**
N	1440	1440	1440	1440	1440
Rho	-	0.423	0.174	0.275	0.275
R^2 within	-	0.30	0.30	-	-
R^2 between	-	0.18	0.47	-	-
R^2 overall	0.37	0.25	0.37	-	-

In brackets: t statistics for OLS, FE and RE-GLS, z values for Instrumental Variables Estimators; * 10% significance level, ** 5% significance level and *** 1% significance level.

Hausman test	Degrees of freedom	Critical value at 5%	Test statistic	P-value
FE-RE GLS	7	14.07	82.37	0.0000
FE – HT	7	14.07	11.41	0.1217
FE – AM	7	14.07	11.59	0.1148

Table 9. Estimation Results – Dynamic Panel Approach

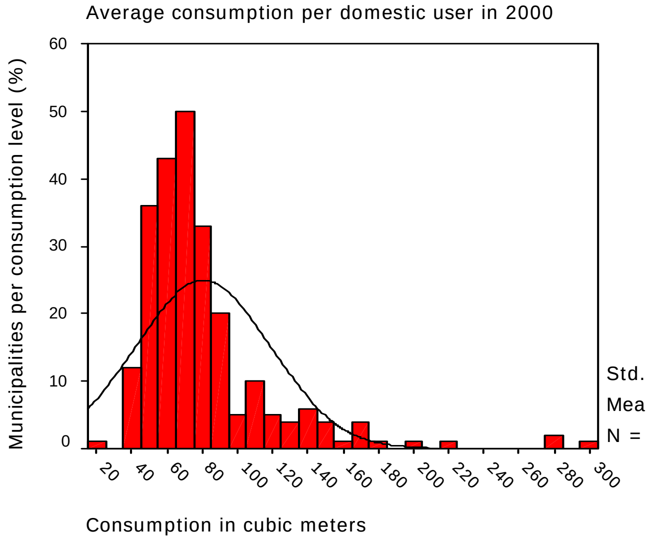
	OLS	FE	AH FD	AB - one step	AB - two step
INTERCEPT	-	4.35	-	-	-
		(6.92)***			
Lagged AVCONS	0.575	-0.034	-0.346	-0.206	-0.233
	(24.76)***	(-1.18)	(-13.43)***	(-5.30)***	(-6.17)***
AP	-0.072	-0.088	-0.080	-0.088	-0.050
	(-3.99)***	(-4.51)***	(-5.12)***	(-4.72)***	(-1.12)
INCOME	0.242	0.090	0.132	0.093	0.063
	(18.74)***	(1.35)	(1.90)*	(1.41)	(1.13)
WT	0.175	0.119	-0.084	-0.049	-0.098
	(3.04)***	(2.09)*	(-1.12)	(-1.07)	(-2.47)
Y_2001	0.408	0.019	-0.053	-	-
	(11.31)***	(0.49)	(1.02)	-	-
Y_2002	-0.183	-0.119	0.046	0.059	-0.043
	(-4.21)***	(-2.81)***	(0.86)	(0.18)	(-1.42)
Y_2003	0.033	-0.007	0.032	0.026	0.055
	(1.34)	(-0.31)	(1.27)	(1.79)*	(4.29)***
Y_2005	-0.057	-0.064	-0.077	-0.072	-0.079
	(-2.89)***	(-3.84)***	(-6.85)***	(-5.06)***	(-4.97)***
N	1200	1200	960	960	960
^{2} Rho		0.68	0.73	-	-
R^2 within	-	0.17	0.08	-	-
R^2 between	-	0.05	0.90	-	-
R^2 overall	0.99	0.07	0.21	-	-

In brackets: t statistics for in AH, z values for all other estimators; * 10% significance level, ** 5% significance level and *** 1% significance level.

Sargan test	Degrees of freedom	Critical value at 5%	Test statistic	P-value
AB one step	9	16.92	26.46	0.0017
AB two step	9	16.54	16.21	0.0627

AB test for autocorrelation	AB one step – AR(1)	AB one step – AR(2)	AB two step – AR(1)	AB two step – AR(2)
Test statistic	-4.84	0.47	-1.55	-0.001
P-value	0.0000	0.6396	0.1204	0.9942

Graph 2. Water domestic consumption per user over 2000 to 2005 in Sardinian towns.


Average consumption per domestic user in 2000

Std. Dev = 38.33

Mean = 80

N = 240.00

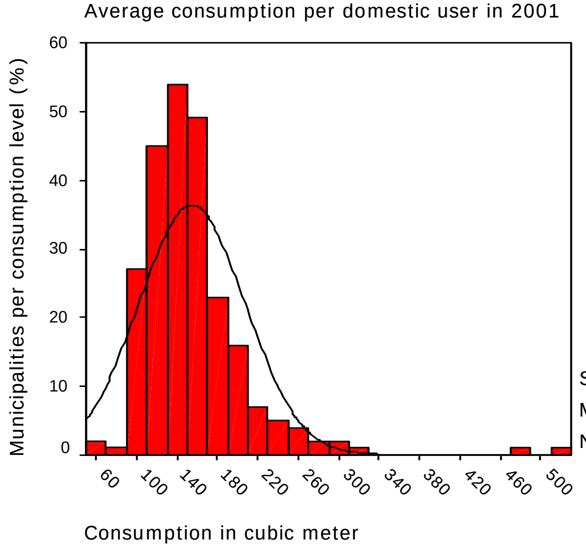
Median = 70.2

Percentiles

25 = 57.2

50 = 70.2

75 = 86.8


Average consumption per domestic user in 2001

Std. Dev = 52.64

Mean = 155

N = 240.00

Median = 145.0

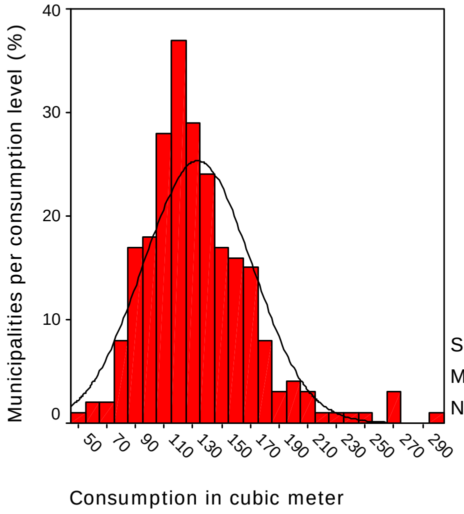
Percentiles

25 = 121.7

50 = 145.0

75 = 171.1

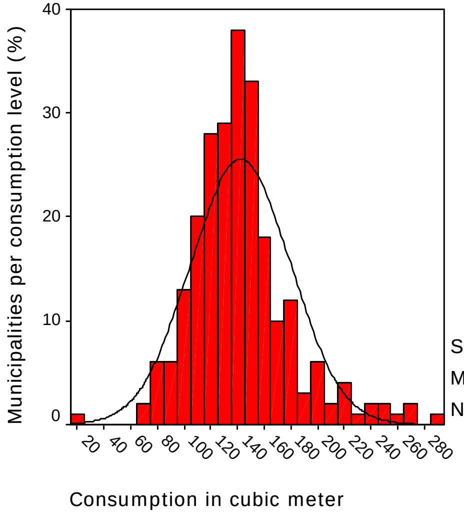
Average consumption per user in 2002



Std. Dev = 37.70
Mean = 133
N = 240.00

Median = 126.7
Percentiles
25 = 108.4
50 = 126.7
75 = 152.0

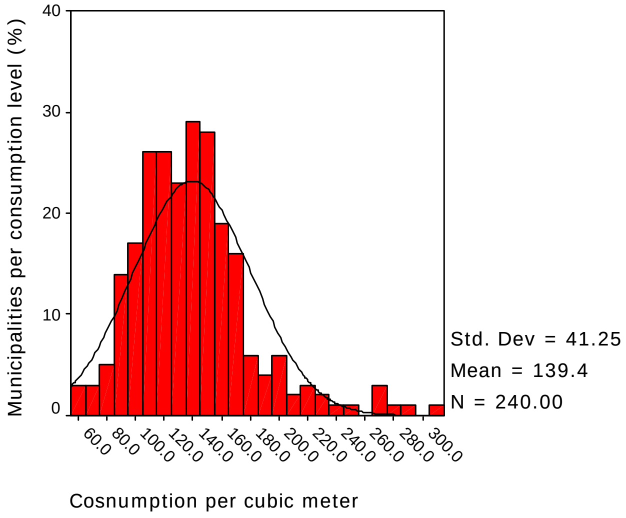
Average consumption per user in 2003



Std. Dev = 37.39
Mean = 142
N = 240.00

Median = 138.6
Percentiles
25 = 119.4
50 = 138.6
75 = 158.6

Average consumption per user in 2004



Median = 135.4

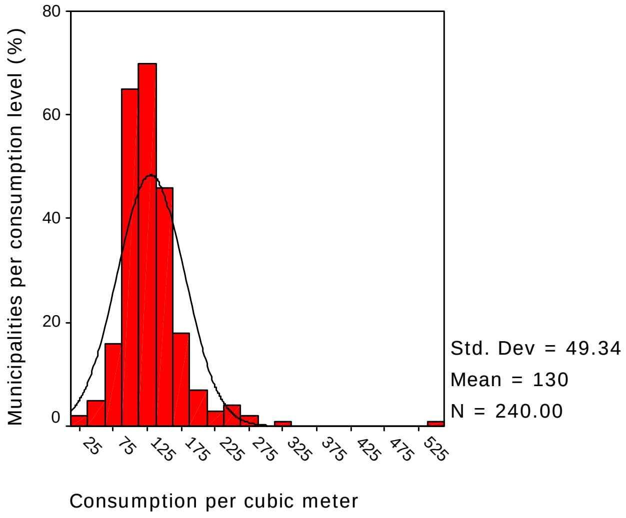
Percentiles

25 = 111.3

50 = 135.4

75 = 157.0

Average consumption per user in 2005



Median = 121.00

Percentiles

25 = 103.7

50 = 121.0

75 = 148.7