The Determinants of Residential Water Demand
Empirical Evidence for a Panel of Italian Municipalities

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Summary

We present empirical evidence on the determinants of residential water demand for one Italian region, Emilia-Romagna, by using municipal panel data. The estimated water demand price elasticity is negative, showing values between -0.99 and -1.33, never significantly different from one, considering different specifications without and with additional socio-economic factors. Income results associated to a positive elasticity, though lower than one. The role of other socio-economic territory-specific determinants is less relevant, with the exception of altitude. The relative high value of price elasticity is deemed consistent with the higher level of Regional water prices compared to the national average. The applied analysis is an important starting point for the Italian environment, which lacks reliable estimates on elasticities concerning microeconomic water demand studies. The estimation of price elasticity and the investigation on the determinants of water demand are necessary steps for both private and private-public management of water resources within the new framework originating from the implementation of the 96/1994 National water bill.

Keywords: Residential water demand, Price elasticity, Income elasticity, Water pricing

JEL Classification: C23, D12, Q25

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I. INTRODUCTION

Two main stems in residential/domestic demand economic oriented analysis are found in the empirical literature. The first deals with the estimation of price or income demand elasticities, exploiting either household data or municipal/provincial data as unit of analysis. The price demand elasticities can be used for water demand management purposes while the income price elasticities can be useful in the forecasting process of the water requirements. The second research direction deals with the estimate of consumer willingness to pay for increasing in water service quality in holistic sense or concerning single characteristics of the service. The aim of the analysis is thus the elicitation of direct use, indirect use and non-use values associated to the water resource consumption, by means of direct or indirect techniques. In this paper we focused the analysis in the first stem of the empirical literature, exploring the topic econometric issues related to the water demand analysis with regard to municipal data.

This paper presents empirical evidence on the determinants of water demand for residential use in the Emilia-Romagna Region, by using municipal data concerning 5 of the 9 Provinces (Bologna, Ferrara, Ravenna, Forlì-Cesena, Rimini). The region, located in Northern Italy, shows a very high level of per capita GDP (around 27.000€ in 2003) and represents the 7% of Italian population. The Region is advanced in the implementation of the water sector reform process, which started in 1994. In Italy, Law 36/1994 sets out a framework for the reorganisation of the entire Italian water industry. It provides both vertical and territorial integration of the water cycle within "optimal management areas" that the Regions are expected to delineate themselves (Massarutto, 2001). Under this new system, prices will be set so as to cover full long-run costs (including a reasonable return on investment), with a single charging method for the entire water cycle. However, the actual implementation of this Law has been quite slow so far on average (Massarutto and Messori, 1998; OECD, 1999). The water sector reform should move water management from a purely public-based ownership and public-oriented water policy to a private/mixed ownership structure and private management of water policies, including pricing policy (Dinar, 2000).

This "privatisation" process, occurring at local level, though still in progress and slow evolving, has already had an impact on tariffs, which have shown a nominal increment of 39% from 1992 to 1998 (2% real increase per year). Water "prices" in Italy and in most countries are actually regulated tariffs, which evolve according to a bilateral contracting mechanism between the private utility and the public regulator. Price increases (i) are correlated to water quality investments, (ii) should be instrumental to sustainable policy aims (iii) must assure a pre-determined profit level water utilities. Trade offs may arise, since the regulatory effort has to weight both public and private goals (Pezzey and Mill, 1998).

Concerning the 125 municipalities here considered for the applied investigation, the nominal increase from 1998 to 2001 is 8,9%, with an average price[1] of 0,72€ over the 4 years of the study. It is worth noting that the average tariff level in Emilia Romagna was already the highest among Italian regions, even in comparison to other northern areas, when Italian water prices started the increasing trend in the early nineties.

[1] Considering the price of the central block of the increasing-blocks tariff structure (three blocks are generally present).

II. THE DATASET AND METHODOLOGY

We exploit a panel dataset consisting of 125 municipalities observed over four years (1998-2001). Data were collected by directly addressing water utilities during 2002, since no official source exists. The final dataset brings together annual municipal water consumption and tariff-related data provided by ten local water utilities and other municipal data (population, surface, households, income, etc.) stemming from official sources. Infra-annual data were not available for many utilities and are affected by low quality and reliability in Italy. Data concerning years before 1998 are only available for a subset of utilities. We decided to maximise the panel dataset (125*4) opting for a balanced panel framework witnessing a good degree of socio-economic heterogeneity across municipalities. In fact, they concern the eastern part of Emilia Romagna, with municipalities located in mountain areas, central urban areas and areas on the Adriatic Sea. It is worth noting that 1998 is a good starting year since the effective implementation of the 1994 National water bill occurred from 1997 on.

We estimate a water demand function:

(1) $W = f(P, I, Z)$,

by specifying a log-linear model where W is the dependent variable (water consumption per capita), P represents the water price explanatory factor, I the municipal income[2], Z a vector of socio-economic variables introduced both as controls and as additional explanatory factors (municipal specific data like altitude, share of rural areas, household size, population age, density of commercial enterprises) of water demand (refer to table 1 for a description of all variables). The addition of explanatory factors is a necessary step in order to verify the robustness of price and income elasticity across different specifications and to explore further water demand determinants (Renzetti, 2002; Nauges and Thomas, 2000).

A note is worthwhile: given the non-linearity of the Italian tariff structure (increasing-blocks tariff structure), a marginal price is not available, differently from other local environments (Nauges and Reynaud, 2001). We decided to use as proxy for water price the central price (medium block) of the tariff structure, the one that should cover average costs of production[3] and it represents the core of the tariff policy[4].

The econometric analysis is based on fixed effects specifications, performing better than random effects models in all water demand regressions examined. A Hausman-type test leads to the rejection of the hypothesis that the fixed effect estimator is indistinguishable from the pooled random effect estimator, indicating that regressors are correlated with fixed effect dummies. The fixed effects model is nevertheless more compatible to municipal data, even from a less technical perspective. We also decided to focus the analysis on static

[2] Official time series data on municipal income are not available. We estimated municipal income for the 4 years by using the Treasury 1998 municipal taxable income data, re-parameterised on the basis of yearly provincial income data provided by ISTAT (National Institute of Statistics).

[3] It is worth noting that endogeneity will be a potential problem in following years, where the full transformation of water public utilities into private managed firms will correlate prices and costs stronger than in the past. For this reason, we believe that in the years 1998-2001 the water price could be considered as exogenous, showing an increasing trend following the implementation of 1994 Bill, but still determined by political factors external to the model.

[4] Specifications including the squared tariff were regressed but lead to less robust results.

specifications to avoid the data losses associated with dynamic panel specifications, preferring instead to fully exploit the rich set of information available for the 125 municipal units. For a preliminary econometric analysis on the same data we refer the reader to Mazzanti and Montini (2004).

III. EMPIRICAL EVIDENCE

We estimate various water demand specifications (tab.2). First, a core specification with only price and income is examined. Price and income are both highly significant, with elasticities respectively of –1,11 and 0,56. The core specification with time effects (least squares with time effects) is statistically different from the specification without dummies on the basis of a likelihood ratio test. It shows a price elasticity of -1.12, and a not significant income effect. We also control for water utility (ten utilities managed water services in the area), including utility-associated dummies: in this case elasticities are slightly lower but the variables maintain their significance. The addition of the water utility interaction terms[5] (specification 2) results in a better goodness-of-fit measure. The 'within R^2' is 0.049 in specification 1 and 0.132 in specification 2. As Veerbeek (2004) notes, the computation of goodness-of-fit measures in panel data models is somewhat uncommon because, at first, one may attach different importance to explaining the within and between variation in the data. Thus, the goodness-of-fit measures are not adequate to choose between alternative estimators, but provide possible criteria for choosing between alternative specifications of the same model. Since the fixed effects estimator is able to explain the within variation, a good measure of goodness-of-fit in our case is the 'within R^2'.

Then, we extend the core specification by adding other socio-economic potential determinants of water demand. Since some of those variables are intrinsically time-invariant (altitude) or official data are available only for one year (i.e. share of rural areas), we interact such covariates with a full time variant factor (i.e. water users, population of the municipality). The management of time-invariant data in panel settings is a general issue, associated to a trade off: the fixed effect model allows for eliminating non observed individual heterogeneity by estimating it in differences, but in the meantime time-invariant explanatory factors are dropped off. A set of extended specifications is thus examined[6], first including socio-economic time-variant elements (population density, household size, shares of population with more than 65 years and less than 19; specifications 1 to 7), secondly (specifications 8 and 9) including time-invariant elements as interaction terms (altitude, elderly ratio). The analysis shows that, though associated to expected signs of the coefficients, the statistical significance of the additional time-variant variables is low, while price and income maintain their significance: price elasticity ranges between -1,11 and -1,33 while income elasticity is between 0,53 and 0,71. Concerning interaction terms (with population), we note that, as expected, the altitude has a negative and significant impact on water consumption

[5] Since the raw utility dummies do not vary over time, we have included a set of interaction terms between utility dummy variables and users (time variant).

[6] To avoid collinearity problems and to check the marginal impact of each element on the "baseline model", we first regress specifications with price, income, and one element at a time. We also control for water utilities and time period effects. The addition of water utilities interaction terms in specifications 3 to 9 reduce the significance level of the income coefficient, although in specifications 8, 3 and 4 the income effect remains significant. The addition of time period effects in specifications 3 to 9 leads to a significant income effect in model 9 only.

(altitude is negatively correlated to the temperature in the municipality) while the elderly ratio presents a negative but not significant coefficient[7]. Final results for analysed specifications are shown in tab.2.

Summing up main results, the empirical analysis shows that the estimated coefficient of the tariff variable arises always significant and with the expected negative sign; price elasticity is negative with a value between -0.99 and -1.33, but not significantly different from one, considering the different specifications. The higher tariffs characterising Emilia Romagna, with respect to other Regions in Italy, justify in our opinion the higher than usual value for price elasticities we find[8].

Considering income, the estimated coefficient (in the basic specification) is positive and significant, while the introduction of utility-specific dummies, of time effects or of other socio-economic variables sometimes gives a not significant coefficient or reduces the significance level. We find income elasticity being in a range between 0,40 and 0,71. When extending the core model, the relevancy of income as explanatory factor decreases, thus showing the necessity of a full and rich analysis to obtain consistent results useful to provide information for policy and forecasting aims. As far as the other socio-economic explanatory factors, we note that the number of inhabitants in the municipality, population density, household size, the shares of both old and young population do not present significant effects. They nevertheless present expected signs on the coefficient. Only altitude seems to negatively influence water demand in a significant way.

IV. CONCLUSIONS

This applied study is an important starting point for the Italian environment, which lacks structured integrated datasets and consequently reliable estimates on elasticities concerning micro-economic oriented water demand studies. We argue that more effort should be targeted to creating datasets bringing together official data with water utility information. Our results concerning price and income elasticities may indicate that, at least in Regions associated to high per capita income and high water tariffs, where the water industry reform process is advanced in its development, the role of price-based policy instrument (the regulated tariff) may be important as a demand-driver, and the price induced effect stronger compared to that of exogenous determinant, like income. The estimation of price elasticity and the investigation on the determinants of water demand is necessary information for both private and private-public management of water resources. For private utility managers, price elasticity is relevant to predict the marginal revenue impact of price increases aimed at funding water infrastructures. The high price elasticity we find here is compatible with a rational profit maximizing behavior in the monopolistic local water market. The extent to which tariff increases are effective in providing funds compared to other financial market sources strictly depends on the price elasticity value. For public regulators both price and income elasticities are crucial to establish sound water saving programmes. This study suggests that, at least in areas that have already experienced a strong trend of tariff increases and currently face higher than average tariffs, water pricing can represent a feasible demand-oriented tool out of the mixed policy kit.

[7] The specification including the interaction terms with the *share of rural areas* has not been considered because of the high correlation between the interaction term and population.

[8] See, for instance, Arbues-Gracia et al. (2002), Martinez-Espineira (2002), Martinez-Espineira and Nauges (2004). Nevertheless, Dalhuisen et al. (2003) in their meta-analysis of water demand empirical studies show price elasticity values in a range with negative upper value much higher than one.

Table 1 - Description of variables

Variable	Source	Variability
Water annual consumption per capita	Water utilities	Across municipalities and over time
Tariff (Water price)	Water utilities	Across municipalities and over time
Income per capita	Our processing on provincial ISTAT and Treasury data	Across municipalities and over time
Household size	Ancitel (National municipality dataset)	Across municipalities and over time
Share population < 19 years	Emilia Romagna Region	Across municipalities and over time
Share population > 65 years	Emilia Romagna Region	Across municipalities and over time
Population/surface (Density)	Emilia Romagna Region	Across municipalities and over time
Water users	Water utilities	Across municipalities and over time
Number of commercial enterprises	Ancitel	Across municipalities and over time
Share of municipal rural area	Our processing on ISTAT agricultural census (2000)	Across municipalities
Elderly ratio	Emilia Romagna Region (2000)	Across municipalities
Altitude	Ancitel	Across municipalities

Table 2 - Water demand econometric specifications

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	-1.7756 (-0.82)	-0.7424 (-0.32)	-10.0260 (-1.61)	-6.6670 (-1.64)	-1.8022 (- 0.68)	-1.7866 (-0.82)	-2.9290 (-1.22)	-13.2027 (-2.02)**	-6.4276 (-0.89)
Tariff	-1.1139 (-4.36)***	-0.9936 (-3.83)***	-1.2758 (-4.57)***	-1.2765 (-4.57)***	-1.1133 (- 4.32)***	-1.1210 (-4.33)***	-1.1852 (-4.51)***	-1.3304 (-4.69)***	-1.2184 (-4.26)***
Income	0.5628 (2.61)***	0.4014 (1.67)*	0.6219 (2.83)***	0.6221 (2.83)***	0.5645 (2.39)**	0.5916 (2.14)**	0.5328 (2.45)**	0.7135 (3.09)***	0.5406 (2.30)**
Population			0.8576 (1.42)					3.5694 (2.42)**	1.7250 (1.59)
Pop density				0.8613 (1.42)					
Household size					0.0117 (0.02)				
% pop ≥ 65 years						-0.0892 (-0.17)			
% pop ≤ 19 years							0.5190 (1.13)		
Altitude x population								-0.6595 (-2.01)**	
Elderly ratio x population									-1.8400 (-0.96)
Within R^2	0.0486	0.1319	0.0537	0.0537	0.0486	0.0487	0.0519	0.0638	0.0560

Notes: n= 500; *t*-statistic in parentheses;
*** 1% significance level, ** 5% significance level, * 10% significance level.

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