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Article

Estimating the Determinants of Residential Water Demand in Italy

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Abstract: The aim of this study was to estimate the determinants of residential water demand for chief towns of every Italian province, in the period 2007–2009, using the linear mixed-effects model estimated with the restricted-maximum-likelihood method. Results confirmed that the applied tariff had a negative effect on residential water consumption and that it was a relevant driver of domestic water consumption. Moreover, income per capita had a positive effect on water consumption. Among measured climatic and geographical features, precipitation and altitude exerted a strongly significant negative effect on water consumption, while temperature did not influence water demand. Further, data show that small towns in terms of population served were characterized by lower levels of consumption. Water utilities ownership itself did not have a significant effect on water consumption but tariffs were significantly lower and residential water consumption was higher in towns where the water service was managed by publicly owned water utilities. However, further research is needed to gain a better understanding of the connection between ownership of water utilities and water prices and water consumption.

Keywords: water; residential water demand; water consumption; water utilities; Italy

1. Introduction

Even if most Europeans have historically been shielded from the social, economic, and environmental effects of severe water shortages, the gap between demand and availability of water resources is reaching critical levels in many parts of Europe [1]. Climate change is likely to exacerbate current pressures on European water resources. Moreover, much of Europe will increasingly face reduced water availability during the summer months, and the frequency and intensity of drought is projected to increase—particularly in the southern European and Mediterranean countries [2].

The European Union and the United Nations have called for the application of the Integrated Water Resources Management concept, which attempts to combine measures of water supply and water demand to enhance sustainable approaches to water-resources management [3,4]. Domestic water-demand management may help to reduce water shortages, and lessen the growing pressure on the environment. Moreover, it may reduce the necessity for the construction of major infrastructure, reducing the need for new investments, and decreasing costs [5]. For this reason, a deep knowledge of the behavior of household users in relation to water consumption is crucial for policy makers and water utilities managers.

Exploring the determinants of water consumption requires consideration of the effects of tariffs and income, but also of many other factors, such as weather conditions, geographical or population characteristics, and household features. Beyond the traditional variables analyzed in the literature (e.g., weather, geographical location, household features), scant attention has been dedicated to variables, such as water utilities ownership, that could affect household water consumption [6–8]. Further research is needed on the role of utility ownership because, as Saurì argued [9], it remains unclear whether changes in governance toward a larger presence of non-public actors have by themselves led to improved water-conservation practices and, therefore, to reductions in water consumption. This lack of clarity is due to the fact that reductions in water consumption seem to affect cities with different systems of water ownership and management.

This article aimed to identify the factors affecting water consumption, including the factor of utility ownership, in 103 provincial Italian capitals for the period 2007–2009 using the linear mixed-effects model.

Research on the Italian water industry has historically been limited due to the lack of a comprehensive database recording the main characteristics of water services and water utilities. Unlike the water authorities in some countries (e.g., Denmark and Portugal), Italian authorities (*i.e.*, Conviri and now the Autorità per l'Energia Elettrica il Gas e il Sistema Idrico (AEEG), which is the Italian Regulatory Authority for Electricity Gas and Water) have not published detailed and complete information about the industry at a national scale (e.g., consumption, tariffs, investments). Analysis of water consumption in Italy has, thus, been possible only at local levels, with the collaboration of one or more water companies.

As Italy has been studied only at local levels [10–12], it is of great interest to study the determinants of water consumption in Italy for a multi-year period at a wider national level to provide broader insights to decision makers, water managers, and politicians.

By focusing on a single country, we were able to eliminate cross-cultural noise arising from specific socio-demographic and socio-economic water-demand trends [13]. Moreover, Italy provided a valuable environment for examining (among other variables that are often considered in the international literature) the influence of different types of ownership of water providers on household water consumption (e.g., through water-conservation programs) because Italy has water companies with different ownership models.

The ownership of water companies is a highly debated issue in Italy. Despite the introduction of Law 133/2008 [14], regarding the compulsory privatization of water services, its enactment was delayed by a contentious referendum in 2011. Nevertheless, privatization of water services in Italy remains currently possible because the management of water and wastewater systems is allowed to be the responsibility of wholly public, mixed ownership, or wholly private companies. In addition, some provincial capitals are still allowed to manage their water service in-house.

2. Literature Review

Since the 1980s, the literature on determinants of water consumption has grown substantially. Arbués *et al.* [15] and Worthington and Hoffmann [16] provided valuable reviews of studies on residential water demand. Worthington and Hoffmann [16] demonstrated that from 1980 to 2006, 86% of empirical studies on water-demand management were from the United States (US), Europe, and Australia. Average per-capita consumption was found to be much higher in Australia and the US than in Europe, which was to some extent due to a higher level of outdoor consumption [13]. Only 24% of the studies reviewed by Worthington and Hoffmann [15] related to Europe. Although studies from the US have remained common since 2006 [17,18], many have also concentrated on developing countries ([19] and references therein), for example, Marinoski *et al.* [20] focused on Brazil and Araral and Wang [21] focused on key cities, states, and/or provinces in Southeast Asia. In addition, many European countries have featured in recent studies concerned with water consumption (Table 1), including France [22,23], Cyprus [24], Spain [25–29], Sweden [30,31], Germany [32], Denmark [33], Greece [34], and Poland [35]. Italy has been studied only with a regional and local focus: Mazzanti and Montini [10] studied the Emilia Romagna Region, Musolesi and Nosvelli [11] studied the Cremona Province, and Statzu and Strazzera [12] studied the island of Sardinia.

Exploring the determinants of water consumption requires the consideration of tariffs and income, but also many other factors, such as population characteristics [12,25,29,32,36,37], population density [38], the presence of immigrants [29] or tourists [12–25], and household features [10,12,26–29,31,32,35,37,39], or house characteristics [12,22,28,29].

Water price is one of the most common tools for managing water demand. The literature has demonstrated that a price increase in water exerts a decrease in per-capita water consumption. Many factors have been presented that may influence price elasticity (*i.e.*, the change in quantity demanded in response to a change in price, holding constant all the other determinants of demand). Worthington and Hoffman's [16] review demonstrated that price elasticity varied between −0.25 and −0.75 because water has no substitute for basic uses, and water bills represent a small proportion of income [5,15,16,40] and references therein. Gaudin [41] reported that price elasticity increased by 30% or more when pricing was provided on the bill.

Table 1. Overview of relevant studies on water demand in European countries: Effects of price and income.

Reference	Authors	Country	Price	Income
[29]	March *et al.* (2012)	Spain		+
[38]	March and Saurì (2010)	Spain		+
[35]	Bartczak *et al.* (2009)	Poland	−	+
[32]	Schleich and Hillenbrand (2009)	Germany	−	+
[12]	Statzu and Strazzera (2009)	Italy	−	+
[11]	Musolesi and Nosvelli (2007)	Italy	−	+
[37]	Martins and Fortunato (2007)	Portugal	−	=
[28]	Domene and Sauri (2006)	Spain	=	+
[27]	Arbués and Villanua (2006)	Spain		+
[10]	Mazzanti and Montini (2006)	Italy	−	+
[34]	Bithas and Stoforos (2006)	Greece	−	+
[39]	García-Valiñas (2005)	Spain	−	+
[26]	Arbués *et al.* (2004)	Spain	−	+
[42]	Garcia and Reynaud (2004)	France	−	+
[43]	Martínez-Espiñeira and Nauges (2004)	Spain	−	+
[36]	Martínez-Espiñeira (2003)	Spain		+
[25]	Martínez-Espiñeira (2002)	Spain	−	+
[24]	Hajispyrou *et al.* (2002)	Cyprus	−	+
[22]	Nauges and Thomas (2000)	France	−	+
[31]	Höglund (1999)	Sweden	−	=
[33]	Hansen (1996)	Denmark	−	

A number of studies have demonstrated that short-run elasticity was smaller than long-run elasticity [11,24,44,45]. Moreover, a meta-analysis conducted by Dalhuisen *et al.* [39] indicated that price elasticity was generally smaller (*i.e.*, price is more inelastic) for higher income countries. Martínez-Espiñeira and Nauges [43] estimated that per-capita water use was highly insensitive to price changes (approximately three cubic meters per capita per month), and suggested that as the threshold is approached, pricing policies barely affect demand. Hansen [33] demonstrated that water consumption in Denmark was more sensitive to the price of energy than to its own price due to the wide utilization of heated water in that country.

Studies focusing on water consumption in a range of countries generally agree that there exists a positive effect of income on water consumption, that is, richer consumers use more water than poorer consumers, even if the difference is small [10,22,27,28]. Dalhuisen *et al.* [40] and Worthington and Hoffman [15] suggested that water demand was rather inelastic to income changes. However, data indicate that income elasticity is generally higher for higher income countries [40].

Many other variables have been investigated to identify which factors affect water consumption globally. Climate is one of the most studied drivers of domestic water demand, as it is believed that water consumption varies depending on variables, such as temperature and rainfall, which may influence the amount and/or frequency of activities that involve water-consumption activities, such as personal-hygiene practices, garden irrigation, and car cleaning.

With respect to weather conditions, Domene and Sauri [28] (researching the Metropolitan Region of Barcelona) and Martínez-Espiñeira [25] (researching Northwest Spain) found that water use was highest in summer. Moreover, Martínez-Espiñeira [25] and Schleich and Hillenbrand [32] (researching Germany) found that water consumption decreased as the number of rainy days increased. Similarly, studies focused on two different regions of Italy reported that water consumption increased in periods of drought and in dry areas [10–12]. In contrast, Arbués and Villanua [27] reported an association between high temperatures and low water consumption in the city of Zaragoza in Spain, which they suggested was due to consumption levels tapering off in the summer because of the outflow of residents to holiday destinations. Researching in Spain also, García-Valiñas [39] observed higher price elasticity in peak (summer) than in off-peak periods (all other seasons). In Portugal, Martins and Fortunato [37] demonstrated that high temperatures increased the demand for water, although rainfall had no significant association with water demand.

With respect to geographical features, Mazzanti and Montini [10] and Statzu and Strazzera [12] found that altitude had a significant negative effect on water consumption in Italy. Statzu and Strazzera [12] suggested their result might have been due to differing characteristics of houses in different territories in Sardinia (*i.e.*, the houses in hilly towns do not generally have gardens, in contrast to those in the valleys and coastal small towns and villages), while Mazzanti and Montini [10] suggested their result was due to the negative correlation of water consumption with temperature in the municipality.

Domene and Saurì [28] demonstrated that consumer behavior was an important explanatory factor in household water consumption, albeit to a lesser extent than other variables (e.g., socio-demographic and economic variables, such as house type and income). Nieswiadomy [46], Michelsen *et al.* [47], Hurd [48], Lee *et al.* [49] and March *et al.* [50] found a discernable influence of the existence of water-conservation programs on water demand. Nauges and Thomas [22] reported that residential water consumption was significantly lower when individual housing with meter recording was present, and they thus encouraged the installation of water metering in collective housing. Similarly, Fielding *et al.* [51] analyzed 221 households fitted with smart water meters and demonstrated that interventions (e.g., water-saving information alone, water-saving information, as well as a descriptive norm manipulation, and water-saving information, as well as tailored end-user feedback) led to significant water savings. However, long-term household usage data has demonstrated that in all cases, the reduction in water use resulting from interventions eventually dissipated, with water consumption returning to pre-intervention levels after approximately 12 months.

Statzu and Strazzera [12] found that home-owners consumed less water than renters did, probably because rent often covers the water bill, and, hence, renters do not receive accurate price signals for their consumption behavior. Statzu and Strazzera also concluded that rationing measures did not have a significant influence on consumption because after the first year—When restrictions were effective in reducing consumption—Users adopted defensive measures, such as water tanks, which offset the regulations imposed. Thus, the authors suggested that quantity restrictions may be effective only when shortages are an exceptional event. In contrast, García-Valiñas [39] demonstrated that restrictions implemented in Seville during the drought seemed to have an important influence on water demands. It has also been found that wells in Germany have a negative effect on per-capita water demand, as would be expected [32].

Until now, scant attention has been paid to water utilities ownership as a factor affecting household water consumption. Over the past 25 years, the global water industry has been the focus of debate on how best to improve the economic performance, organizational efficiency and financial viability of water utilities. Water services have accordingly been privatized in several countries, notwithstanding conflicts between the profit-seeking behavior of private partners and the public objectives of a water service. With reference to the United Kingdom (UK), Howarth [6] demonstrated that there was no financial incentive for private water companies to actively manage water demand to reduce it. What is arguably in the best interests of three stakeholders of water utilities (*i.e.*, community, customers, and environment) is in direct conflict with the interests of private shareholders of water companies (*i.e.*, the main stakeholders of privatized companies). Moreover, Howarth [6] highlighted that UK water companies have been extremely uncomfortable with the idea of promoting conservation programs and working with their customers to solve the supply–demand problem (which does not involve the provision of additional water resources), despite that fact that an increasing number of customers seem to be interested in programs that aim to save water and conserve the environment.

Barrett and Wallace [8] demonstrated that in Australia and the UK, water-conservation programs increased water suppliers' costs, and reduced revenues and returns to shareholders. The two latter effects are particularly relevant in the case of privately owned water companies. Barrett and Wallace [8] provided support for the hypothesis that water utilities are more likely to incur the costs of an effective water-conservation program when there is a greater degree of government control, through either ownership or regulation. This highlights concerns with prevailing global trends toward privatization of water supplies. Similarly, Kallis *et al.* [7] argued that the state was important in legitimizing and guiding conservation behavior, whether the water utility be publicly or privately owned. In particular, they demonstrated that California's public water utilities appeared to be more proactive and target oriented in encouraging their customers to conserve water than were their private counterparts.

In light of the above considerations, and according to Dalhuisen *et al.* [40], additional research on determinants of water consumption is necessary. This study aimed to contribute to the advancement of knowledge on determinants of water demand by focusing on Italy, where data are available only at local levels. In addition to commonly studied variables, such as tariffs, income, weather and geographical characteristics, water utilities ownership was included as a factor that could affect household water consumption. This study applied linear mixed-effects modeling, which, to date, has been used in several studies on residential water demand in Europe [25,31,37].

3. Methods

3.1. Data Collection

Table 2 reports the variables used. In the current study, the dependent variable was the average consumption of drinking water for domestic use (CONSUMPTION) in the chief towns of each Italian province (*i.e.*, liters per capita per day). Thus, as in previous studies [10–12,32], we used community-level data instead of household-level data. Household-level data would have been preferable for estimating determinants of residential water demand [16], but such data were unavailable. Although not optimal, community-level data did allow us to analyze the Italian context from north to south, including the islands.

We collected these data using recent Italian National Institute of Statistics (Istat) data [52]. Using Istat databases we also collected information for each province investigated, including population served (POP), altitude at the center (ALT, in m) of the chief town, average annual precipitation (PREC, in mm), and average annual mean temperature (TEMP, in °C). We gathered information about the annual expenditure for residential household use of 192 cubic meters of water (TARIFF), including fees for water, wastewater and sewerage services, the fixed component, and value added tax (VAT) from reports compiled by Cittadinanzattiva (an Italian non-profit organization founded in 1978 and recognized as a consumer organization since 2000) [53]. As with the information about consumption from Istat, these data were available only for the chief town of each Italian province. The Cittadinanzattiva data estimated 192 cubic meters of water as the average annual consumption of a three-member household.

Table 2. Definition of variables.

Variable	Description
CONSUMPTION	Average consumption of drinking water for domestic use in the chief towns of each Italian province (liters per capita per day)
ALT	Altitude at the center (in meters)
TEMP	Average annual mean temperature (in °C)
TARIFF	Annual expenditure for residential household use of 192 cubic meters of water
INCOME	Average taxable income of individuals per capita in the chief town of each Italian province
OWNERSHIP	Wholly publicly owned utilities (1) or not publicly owned utilities (0)
PREC	Average annual precipitation (in mm)
YEARS	Observed year (1 for the first year; 2 for the second and 3 for the third)
GEOGRAPHICAL AREA	The location of the chief town: North, center and south of Italy
POP	Population served

We collected data on the average taxable income of individuals per capita (INCOME) in the chief town of each Italian province based on data from the Ministry of Economy and Finance, which are publicly available online. This information was available for the three-year period 2007–2009 of this study for the chief towns of 103 Italian provinces. Although currently there are 106 provinces in Italy, three of them became effective in 2009, and thus were excluded. Four Sardinian provinces created in 2005 but abrogated following a referendum in 2012 were also excluded, as the necessary data were unavailable.

We collected information about the water utilities that manage the water service in each chief town, and classified these utilities by their ownership (OWNERSHIP) with a dummy variable: 1 for wholly publicly owned water companies and 0 for not publicly owned water companies.

3.2. Linear Mixed Models

Linear models represent the relationship between a dependent or response variable y and a vector of auxiliary variables $\mathbf{x}$. Three basic hypotheses are assumed for these models: Linearity, normality, and independence [54–56]. Linear models assume that observations are drawn from the same population and are independent. Linear mixed models handle data in which observations are not independent. Linear mixed models have a complex multilevel or hierarchical structure. Observations in different levels (clusters) are assumed to be independent, but observations within the same level are considered dependent because they share common properties. There are two sources of variation: Between and within clusters. Linear mixed models consider the following:

(1) Random effects: Sometimes the number of levels of a categorical explanatory variable is so large (with respect to sample size) that introduction of fixed effects for its levels would lead to a poor estimation of model parameters. If this is the case, the explanatory variable should not be introduced in a linear model. Mixed models solve this problem by treating the levels of the categorical variable as random, and then predicting their values.
(2) Hierarchical effects: Response variables are often measured at more than one level, for example, in nested territories in small area estimation problems. This situation can be modeled by mixed models; this ability is one of their appealing properties.
(3) Repeated measures: When several observations are collected on the same individual, the corresponding measurements are more likely to be correlated than independent. This happens in longitudinal studies, time-series data or matched-pairs designs.
(4) Spatial correlations: When there is correlation among clusters due to their location, for example, the correlation between nearby domains may give useful information to improve predictions.

Research treating linear mixed models includes Searle, Casella and McCullogh [57], Longford [58], McCullogh and Searle [59], and Demidenko [60].

Let $\mathbf{x}_{ij}$ denote a vector of p auxiliary variables for each observation j in cluster i, and assume that y_{ij} is the variable of interest. A linear mixed-effects model is

$$y_{ij} = \mathbf{x}_{ij}^T\beta + d_{ij}u_i + \varepsilon_{ij}, \quad j = 1,\dots n_i,\ i = 1,\dots m \tag{1}$$

where β is the $p\times 1$ vector of regression coefficients, u_i denotes a random group effect that characterizes differences in the conditional distribution of y given x between the m groups, d_{ij} is a constant whose value is known for the observations on, and ε_{ij} is the error term associated with the jth unit within the ith cluster. Conventionally, u_i and ε_{ij} are assumed to be independent and normally distributed with mean zero and variances of σ_u^2 and σ_ε^2, respectively. Let us first assume that the variance components of linear mixed model are known. The regression parameter β can be estimated by applying the weighted least-squares method. Given the estimated values of β, there are several fitting methods for the variance components of linear mixed models. The three most common are maximum likelihood, restricted maximum likelihood, and Henderson III. For more details on the estimation methods see Searle, Casella and McCullogh [57]. In this study, we used the estricted-maximum-likelihood method, with the response variables being CONSUMPTION; the auxiliary variables being YEARS, TARIFF, INCOME, GEOGRAPHICAL AREA, ALT, PREC, TEMP, POP, and OWNERSHIP; and the group being represented by the three measures of CONSUMPTION for the company ith. The linear mixed-effects model can be expressed as:

$$\begin{aligned} CONSUMPTION_{ij} &= \beta_0 + \beta_1 YEARS + \beta_2 TARIFF + \beta_3 INCOME + \beta_4(north) + \beta_5(south) + \beta_6 ALT + \beta_7 PREC \\ &+ \beta_8 TEMP + \beta_9 POP + \beta_{10}(Public) + company_i \end{aligned} \tag{2}$$

Further, we fitted the linear mixed model with TARIFF as response variable and YEARS, INCOME, GEOGRAPHICAL AREA, ALT, PREC, TEMP, POP, and OWNERSHIP as covariates. Additionally, in this model the group being represented by the three measures of TARIFF for the company *ith.* The linear mixed model became:

$$TARIFF_{ij} = \beta_0 + \beta_1 YEARS + \beta_2 INCOME + \beta_3 (north) + \beta_4 (south) + \beta_5 ALT + \beta_6 PREC + \beta_7 TEMP + \beta_8 POP + \beta_9 (Public) + company_i \quad (3)$$

The linear mixed models are fitted using the default REML option of the *lme* function (see Venables and Ripley, Section 10.3 [61]) in R, that is a language and environment for statistical computing and graphics [62].

4. Results and Discussion

Table 3 provides some descriptive statistics of the variables, and Table 4 presents the matrix of correlations among the measured variables.

Table 3. Descriptive statistics.

Year		CONSUMPTION	TARIFF	PREC	TEMP	INCOME	POP
	Mean	175.00	231.17	635.27	13.74	13,593.75	163,407.70
2007	Min	97.39	106	419.3	4.3	7,712	21,517
	Max	243.41	445	905.7	18.5	21,249	2,556,724
	Mean	171.86	241.89	849.42	13.62	13,709.99	163,666.49
2008	Min	97.46	106	428	3.4	7,771	21,712
	Max	248.48	445	1378.7	18.7	21,529	2,572,486
	Mean	170.15	256.77	870.41	13.48	13,744.05	163,863.81
2009	Min	97.06	106	449	1.8	7,953	21,679
	Max	241.09	421	1209.3	19.15	20,922	2,576,803

Table 4. Correlation matrix.

Variable	CONSUMPTION	ALT	TARIFF	INCOME	PREC	TEMP	OWNERSHIP	YEARS	POP
CONSUMPTION	1.000	−0.224	−0.463	0.332	0.063	−0.179	0.119	−0.082	0.278
ALT	−0.224	1.000	−0.136	−0.144	−0.029	−0.207	0.172	0.000	−0.201
TARIFF	−0.463	−0.136	1.000	−0.123	−0.167	0.199	−0.394	0.147	−0.069
INCOME	0.332	−0.144	−0.123	1.000	0.220	−0.537	−0.125	0.000	0.154
PREC	0.063	−0.029	−0.167	0.220	1.000	−0.281	0.014	0.022	0.016
TEMP	−0.179	−0.207	0.199	−0.537	−0.281	1.000	0.011	0.519	0.073
OWNERSHIP	0.119	0.172	−0.394	−0.125	0.014	0.011	1.000	−0.036	−0.141
YEARS	−0.082	0.000	0.147	0.000	0.022	0.519	−0.036	1.000	0.000
POP	0.278	0.201	0.069	0.154	0.016	0.073	0.141	0.000	1.000

The average consumption of drinking water for domestic use decreased between 2007 (175 L per capita per day) and 2009 (170 L per capita per day). Consumption in 2002 was 206 L, with a decrease over the subsequent 10 years of approximately 15% [52]. Unlike consumption, average expenditure for residential household use increased between 2007 and 2009, from a mean of €231 to €256. Minimum expenditure was in Milan (€106 all three years), followed by Isernia (€114 in 2009). In 2009, maximum expenditure was €421 in Florence, followed by Agrigento (€419) and Arezzo (€414). Agrigento, where consumption was the lowest, had the highest water tariff in both 2007 and 2008. It is worth mentioning that eight of the chief Italian towns with the ten highest tariffs were in Tuscany, where most water utilities have mixed ownership. In fact, only one Tuscan chief town, Massa, had a publicly owned water utility, and an average expenditure of €291. Another exception was Lucca, which had a mixed-ownership water utility that served only that municipal area.

In the analysis period, the average annual precipitation increased consistently, from an average 635 mm in 2007, to 849 mm in 2008, and 870 mm in 2009. The minimum and maximum levels also increased. In 2009, less than 700 mm of precipitation was registered in Sicily and Sardinia. The average annual temperature remained stable, at ~13.5 °C, although the minimum temperature decreased (from 4.3 °C in 2007 to 1.8 °C in 2009 in Aosta), and the maximum temperature increased (from 18.5 °C in 2007 to 19.1 °C in 2009, in Syracuse and Reggio Calabria, respectively). The minimum level of water consumption remained quite constant, at approximately 97 L in Agrigento in Sicily, mainly due to interruptions in water supply. This was the only chief Italian town with a daily water consumption of fewer than 100 L per capita. Approximately 18.4% of the chief towns consumed 200–240 L of drinking water per inhabitant per day, with approximately half (55%) consuming 150–200 L and 24.3%, 100–150 L.

The average taxable income per capita also increased from 2007 to 2009, from a mean of €13,594 to a mean of €13,744. The gap between the minimum and the maximum level of average taxable income decreased in this period.

Chief towns of Italian provinces have on average ~163 thousand inhabitants, with a minimum of ~21 thousand and a maximum of more than 2.5 million of inhabitants.

Fifty-five cases (53.4%) are wholly publicly owned water companies. Ownership of water companies that are not publicly owned is either wholly private (six cases, or 5.8% of the total sample) or mixed, with public and private shareholders (42 cases, or 40.8%). Of the wholly publicly owned group, eight (7.8%) were in chief towns where the water services are managed directly by the Town Hall or province. It is worth mentioning that wholly private water companies operate only in the chief towns of southern Italy.

Our dataset included towns whose altitude at the center averaged 171 m, with a minimum of two (Venice) and a maximum of 931 m (Enna). There are 21 chief Italian towns located on the coast with an altitude of 10 m or less, and nine with an altitude higher than 500 m, seven of which are in the south or on the islands. The provinces are distributed as follows: 45% in the north, 20% in the center, and 35% in the south.

We first examined the results of our model, including all variables (Model 1) presented in Table 5.

Based on the significance test and the signs of parameter estimates, the data demonstrated that as expected, TARIFF and INCOME had a significant effect on Italian residential water consumption. This was confirmed by the reduced model (Model 2, Table 6), which demonstrated that increasing the tariff level caused a reduction in residential water consumption, while increasing the income per capita increased consumption.

Our results confirmed the findings of many empirical studies on water consumption in European countries. That is, the tariff applied on water use has a strong negative effect on residential water consumption, while income per capita has a positive effect on water consumption. As such, water consumption decreases when a tariff growth is recorded. Thus, according to the literature, tariffs are frequently used as a tool for improving water savings [63]. The implementation of efficient water-pricing practices that promote equity, efficiency and sustainability in the water sector is probably the simplest conceptual instrument, but perhaps the most politically difficult to implement [64].

Using tariffs as a manner in which to regulate water consumption could potentially have a greater effect on lower income households, since water has no substitutes for basic uses and there is an amount of water that is highly insensitive to price changes [45]. Moreover, according to the literature [11,40,65], in the short term, residential water demand seems to be inelastic at current prices.

Table 5. Model 1 (water consumption as response variable, including all variables).

Variables	Value	Std. Error	DF	*t*-Value
(Intercept)	188.82	27.60	200	6.84 ***
YEARS	0.126	1.29	200	0.92
TARIFF	−0.169	0.03	200	−4.80 ***
INCOME	0.002	0.00	200	1.63 *
Geographical area (north)	3.324	7.59	98	0.43
Geographical area (south)	−9.675	9.46	98	−1.02
ALT	−0.027	0.01	98	−2.01 **
PREC	−0.010	0.00	200	−1.62 *
TEMP	0.687	1.01	200	0.68
OWNERSHIP (Public)	5.991	5.53	98	1.08
POP	0.000	0.00	200	2.47 **
σ_u	23.108	AIC	2722.22	
σ_e	12.207	BIC	2770.282	

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Table 6. Model 2 (water consumption as response variable, including only significant water-consumption determinants).

Variables	Value	Std. Error	DF	*t*-Value
(Intercept)	187.478	14.83	202	12.63 ***
TARIFF	−0.177	0.03	202	−6.34 ***
INCOME	0.003	0.00	202	3.16 ***
ALT	−0.033	0.01	101	−2.78 ***
PREC	−0.010	0.00	202	−2.11 **
POPULATION	0.000	0.00	202	2.29 **
σ_u	22.664	AIC	2735.63	
σ_e	12.227	BIC	2765.34	

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Among climatic and geographical features, only ALT and PREC had a strongly significant negative effect on residential water consumption. Thus, water consumption in Italy was found to be higher at lower altitudes, and increase in periods of drought and in dry areas. This agrees with previous studies for Emilia Romagna and Sardinia [10–12], and Germany [32]. As such, the outcomes related to climatic and geographical features should encourage managers and politicians to employ *ad hoc* behaviors, investing more in activities that are useful for reducing water consumption in dry and drought areas, or in low-altitude areas [66]. Moreover, POP had a positive effect on water consumption: So, according to previous empirical findings [12], small towns were characterized by lower levels of consumption.

OWNERSHIP itself did not have a significant effect on water consumption. Considering TARIFF as the response variable instead of CONSUMPTION, the data demonstrated (see Table 7) that water prices increased significantly (1% significance level) in the observed period, and that the TARIFF was significantly lower (1% significance level) in publicly owned water utilities than in mixed-ownership or wholly private water utilities. As such, the effect of TARIFF on water consumption prevails on the effect of OWNERSHIP.

Table 7. Model 3 (water price as response variable, including all variables).

Variables	Value	Std. Error	DF	*t*-Value
(Intercept)	329.32	45.51	201	7.23 ***
YEARS	15.438	1.31	201	11.73 ***
INCOME	−0.003	0.00	201	−1.00
Geographical area (north)	−56.622	17.16	98	−3.30 ***
Geographical area (south)	−52.268	20.69	98	−2.52 **
ALT	−0.036	0.03	98	-1.18
PREC	−0.019	0.00	201	−2.59 **
TEMP	1.19	1.65	201	0.72
OWNERSHIP (Public)	−43.609	12.83	98	−3.39 ***
POP	−0.000	0.00	201	1.69 *
σ_u	57.911	AIC	2926.764	
σ_e	13.512	BIC	2971.169	

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

In fact, when the variable TARIFF was excluded from Model 1 (see Table 8), OWNERSHIP significantly affected CONSUMPTION, that is, residential water consumption was significantly higher in towns where the water service was managed by publicly owned water utilities.

Table 8. Model 4 (water consumption as response variable, excluding TARIFF as a determinant of Italian residential water consumption).

Variables	Value	Std. Error	DF	*t*-Value	*P*-Value
(Intercept)	124.777	14.50	203	8.60	0.0000 ***
ALT	−0.027	0.01	100	−2.03	0.0446 **
YEARS	−3.516	0.85	203	−4.13	0.0001 ***
OWNERSHIP (Public)	13.948	5.43	100	2.56	0.0118 **
INCOME	0.003	0.00	203	3.52	0.0005 ***
POPULATION	0.000	0.00	203	2.67	0.0081 ***
σ_u	25.917	AIC	2737.163		
σ_e	12.168	BIC	2766.873		

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

These results are consistent with Hall's [67] study, which highlighted that privatization is likely to increase water prices. Moreover, our results supported the idea that publicly owned water utilities (and the politicians involved in their management [68]) might be more interested than their private counterparts in satisfying citizens' water needs and, at the same time, imposing lower water tariffs despite the detrimental effect this has on water sustainability and environmental preservation. Indeed, public enterprises could be more interested in serving the goals of politicians, which are associated with ensuring success in elections and long tenures in power through the provision of benefits such as low-cost goods and services such as water. As such, in contrast with the suggestions of Howarth [6], it seems that publicly owned utilities do not have a higher incentive to reduce water consumption through the most common tool for managing water demand (*i.e.*, water price) than do wholly or partially privatized water utilities.

For these reasons, policies on household water conservation aimed at saving water and conserving the environment should be adopted by publicly owned water utilities, which represent more than half of the companies that manage the water service in the chief towns of Italian provinces. Shareholders of these utilities consist of one or more municipalities or provinces, public entities whose interests should lie in community, customers, and environment, and who should wish to promote sustainable approaches to water consumption and help reduce current pressures on European water resources.

It is relevant to state that the cross-sectional nature of the relationship between water prices and ownership may reflect not only the pricing behavior of public *versus* private utilities, but also the fact that there may be fundamental differences in consumption patterns that drive certain towns to privatize their water supplies. Moreover, towns with private *versus* public utilities may differ along a variety of observable and unobservable characteristics that should be investigated further. In fact, data showed that also POP significantly influenced residential water consumption (see Tables 5 and 8), even if this variable exerted only a limited negative effect on water price (10% significance level, see Table 7). Moreover, using a generalized linear mixed model (with binomial link; for details, see [59]), we found that ownership of the water utilities was influenced by the population served, so that the higher the population, the lower the probability that the water utility was wholly publicly owned, while the average income of the town seemed not to drive the decision to privatize water supplies. As such, further research is needed to gain a better understanding of whether higher consumption and lower tariffs in towns where the water service is managed by publicly owned water utilities might be due to other observable characteristics of the towns such as housing characteristics or other municipality characteristics [22].

5. Conclusions

By using the linear mixed-effects model estimated with the restricted-maximum-likelihood method, we investigated the determinants of residential water demand for chief towns of every Italian province in the period 2007–2009. Our empirical findings demonstrated that increasing the tariff levied to customers caused a reduction in residential water consumption, while increasing the income per capita increased consumption. Considering climatic and geographical features, our data demonstrated that both altitude and precipitation exerted a strongly significant negative effect on consumption. Further, population served has a positive effect on consumption, so that bigger towns showed a higher residential water demand.

Moreover, we found that water utilities ownership itself did not have a significant effect on water consumption. We also found that water prices were significantly lower in publicly owned water utilities than in mixed-ownership or wholly private water utilities, and that the effect of water prices on consumption prevailed over the effect of the ownership structure. Thus, when we excluded the applied tariff independent variable, we found that water consumption was significantly higher where the water service was managed by publicly owned water utilities.

However, the cross-sectional nature of the relationship between water prices and ownership may reflect the fact that towns with private *versus* public utilities may differ along a variety of characteristics, such as size in terms of population served. As a matter of fact, our results showed that the ownership of the water utilities was influenced by the population served, so that the higher the population, the lower the probability that the water utility was wholly publicly owned. Although the population served exerted only a limited negative effect on water price (10% significance level), our results did not allow to rule out the possibility that publicly owned water utilities, which applied lower tariffs, may simply be located in towns where the marginal cost of supplying water is lower. As such, further research is needed to gain a better understanding of whether higher consumption and lower tariffs in towns where the water service is managed by publicly owned water utilities might be due to other observable characteristics of the towns such as housing characteristics or other municipality characteristics [22].

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Author Contributions

Giulia Romano conceived and designed the empirical research, collected the dataset, wrote the literature review, data collection and results and discussion Sections. Nicola Salvati designed the method, analyzed the data and wrote the methods Section. Andrea Guerrini participated in the data collection and wrote the introduction and conclusions Sections.

Conflicts of Interest

The authors declare no conflict of interest.

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