Price elasticity of water demand considering scarcity and attitudes

Paola Garrone, Politecnico di Milano

Luca Grilli, Politecnico di Milano

Riccardo Marzano, Sapienza Università di Roma

Corresponding author: Riccardo Marzano, Department of Computer, Control and Management Engineering, Sapienza Università di Roma, Via Ariosto 25, 00185, Rome, Tel. +39 06 77274, riccardo.marzano@diag.uniroma1it.

Abstract

The effectiveness of price as a water conservation measure remains an open empirical issue and relevant policy question. We conduct a meta-regression analysis to single out location and community traits that boost or depress the price elasticity of residential demand. Our results reveal that water scarcity exerts significant influence on price elasticity. More specifically, if water scarcity is severe, household responsiveness to prices decreases, though this effect is attenuated in environmentally concerned communities.

Keywords: price elasticity, water demand, water scarcity, environmental attitudes

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1. Introduction

Water scarcity is a global issue with localized relevance and impacts in different areas of the planet (e.g. the Middle East, the South of Europe, the U.S. West Coast, Cape Town, etc.). Water managers and policymakers are struggling to meet water conservation goals, spurred by environmental and demographic challenges (such as climate change, deforestation, population growth, urbanization), mostly through command-and-control approaches, including stopgap measures under some circumstances. At the same time, they are increasingly taking demand management strategies (DMSs) into consideration as a means to bring about water-use efficiency (Renwick and Green, 2000; Martínez-Espiñeira and Nauges, 2004; Mansur and Olmstead, 2012; Grafton et al., 2015; Grafton et al., 2011; Asci et al., 2017; Beecher and Gould, 2018; Rougé et al., 2018).

Although price measures have been the first and most natural of the DMSs (Olmstead, 2010), their implementation is still hindered by a limited understanding of consumer responsiveness to water price signals. In fact, despite extensive efforts of empirical environmental economics to obtain consistent estimates of the price elasticity of the water demand, a few issues remain open. Many authors have challenged the presumption of price-elastic water demand (Barrett, 2004; Worthington and Hoffman, 2008); more generally, it remains unclear how water consumers react to water price depending on community-level as well as individual-level characteristics (Dieu-Hang et al., 2017).

In turn, the heterogeneity that affects price elasticity estimates prompted past systematic reviews that were conducted to identify and assess the factors that appear to most affect price elasticity. The primary concern in this search was the control for diverse demand specifications and data characteristics, different price schemes and the different estimation techniques adopted across studies (Espey et al. 1997; Dalhuisen et al. 2003; Sebri, 2016; Marzano et al., 2018). Previous reviews, apart from considering household location, did not investigate in depth to what extent geophysical water availability has a moderating effect on consumer responsiveness to water price changes. Pressures on water resources globally will be exacerbated in the future due to climate change and population growth in metropolitan areas. Water scarcity is the main justification for the recent emphasis globally on water conservation goals. Nonetheless, evidence on how consumers react to water pricing under different water scarcity scenarios is still scarce.

In this paper, we apply a meta-analysis to investigate whether water price elasticity is contingent on the local geographical context, in particular with respect to water scarcity. The analysis uses a meta-sample of primary studies, from 1964 to 2013. The meta-analysis setting allows water scarcity to vary by using water demands estimated in different locations.

Water scarcity may play a crucial role in shaping customers' responsiveness to water pricing. People might exhibit a greater willingness to save water when pricing is used to cope with the water scarcity affecting their community. Scarcity might also affect the interaction between economic incentives and intrinsic motivations in differentiated (and perhaps unexpected) ways.

Greater scarcity implies stronger rivalry in consumption, since under a scarcity scenario each unit consumed reduces substantially what is available to others (Molinos-Senante and Donoso, 2016). Thus, water use decisions of individuals should be modeled by taking into consideration not only the marginal benefit of consumption but also “other-regarding” opportunity cost (Pfaff et al., 2015). Accordingly, experimental studies by Osés-Eraso et al. (2008) and Osés-Eraso and Viladrich-Grau (2007) found that resource use falls with increasing scarcity. Others show that individuals react to scarcity by becoming less cooperative (Blanco et al., 2015; D'Exelle et al., 2009), as a result of stronger competitive pressures among users (Prediger et al., 2014) or impaired cognitive functions, namely the tendency to borrow from the future and ignore the potential for welfare-enhancing collective action (Shah et al, 2012; Mani et al., 2013). None of these studies has examined the moderating effect of scarcity on the effectiveness of monetary (pricing) incentives.

We contribute to the research literature by taking advantage of the geographical variation in the data used to estimate water demand by the primary studies included in our meta-sample. We show that, on average, water scarcity reduces the price elasticity of residential water demand, that is, the responsiveness of usage to changes in prices. In addition, by relying on a subsample of studies using U.S. data, we further analyze how environmental attitudes of communities shape this finding. We find that, on average, a high level of attention toward environmental issues dampens price elasticity; it also moderates the negative effect of water scarcity on price elasticity. We control for a wide array of study-specific and location-specific factors, such as demand specification, data characteristics, price and tariff structures, and estimation techniques adopted across studies.

The analysis of the role that water scarcity plays in shaping consumers' responsiveness to water pricing represents an important step toward targeted policy interventions in the field. In fact, a deeper understanding of the interactions between economic stimuli, local water supply and demand conditions, and the water-saving attitudes of consumers could foster the introduction of more effectively tailored DMSs, and provide policymakers and utility managers with useful criteria for the design and implementation of pricing policies.

Our work also contributes to the deliberation on sustainable consumption and its relationship with prices, individual socio-economic features, and psychological factors, such as attitudes, knowledge, perceptions, and values (Van den Bergh, 2008; Pérez-Urdiales and García-Valiñas, 2016; Schubert, 2017; Ito et al., 2018). Environmental attitudes have been found to be strong predictors of household conservation behaviour or habits (Martínez-Espiñeira et al., 2014) and adoption of water-efficient equipment (Millock and Nauges, 2010; Martínez-Espiñeira et al., 2014). In this study, we add a new perspective on the topic and complement the analysis of the effect of environmental concerns on sustainable consumption by taking into account the context-specific water availability scenario.

The rest of the paper is organized as follows. Section 2 provides the theoretical framework on the relationship between water scarcity and price elasticity. Section 3 presents the data and defines the methodology. Section 4 shows the main results. Section 5 describes the robustness checks performed to support the empirical findings. Section 6 concludes and discusses the implications of the findings.

2. Water scarcity, price elasticity, and intrinsic motivations to save water

In the present study, an analysis has been conducted to establish whether and how water scarcity drives household responsiveness to economic instruments aimed at achieving water saving goals. There are very few available results on this topic in the literature and these are not univocal. Krause et al. (2003) suggest a water price elasticity that is relatively sensitive to water scarcity regimes, while Monteiro and Roseta-Palma (2011) claim instead that water price elasticities are related to consumer preferences but do not vary according to water scarcity.

Standard microeconomics predicts that given user preferences for water and water price, scarcity may constrain water consumption at well below the users' optimal choice. Suboptimal water consumption levels (from a utility maximizer's perspective) can be due to measures aimed at dealing with water crises.[1] Although these low-cost DMSs may be temporal and water use is expected to return to previous patterns when they are removed, water consumption will inevitably be impacted. Moreover, although these measures are considered alternatives to price mechanisms, the aim of guaranteeing universal access to water so as to maintain public safety makes their use inescapable to a considerable extent.

If water scarcity is particularly severe, as in prolonged drought episodes, the effectiveness of pricing mechanisms may be impaired because part of the expected decrease in water demand as a result of a price increase has already been obtained through alternative DMSs.

This expected result is based on a restrictive assumption that intrinsic motivation is an exogenously given constant and can be accordingly disregarded when investigating the effect of economic incentives on resource use. However, some have suggested that the environmental aspect of water resource availability will influence consumption (Dascher et al., 2014). If intrinsic motivations substitute, or complement, price increases and other extrinsic motivators, water price elasticities are likely to vary according to water users' environmental attitudes. Water consumers may be concerned about water conservation issues, both as individuals and members of the local community, and exposure to water-saving standards or other policies may make people engage in water conservation out of a sense of moral duty or public spiritedness (Kaiser et al., 1999).

People who exhibit environmental concerns have preferences for water that are different from those displayed by people who do not. When solving their maximization problem and choosing how much water to consume, the former incorporate other-regarding preferences and somehow internalize part of the external environmental costs associated with water consumption in their utility function (Pfaff et al., 2015). They end up engaging in water conservation actions and cutting their discretionary water consumption.

Having less room for further consumption cuts, water users in communities characterized by higher environmental attitudes are expected to be less sensitive to extrinsic mechanisms to bring about water saving. Though increasing water prices remains a viable strategy to further reduce consumption, water demand would end up being affected only to a marginal extent.[2]

In our conceptualization, intrinsic motivations and water scarcity can interact with price incentives and accordingly lead to differentiated responses in terms of water use. Since the degree of environmental attitudes is related to water-use patterns, not only we expect lower average water price elasticities in environmentally concerned communities, but also different reactions to prices depending on environmental attitudes in communities as water scarcity becomes more severe.

In communities where the population is less concerned with environmental issues, price response is expected to be influenced by water availability. When water is regularly available, water users in these communities are more likely to indulge in discretionary water consuming activities (Willis et al., 2011). Accordingly, increasing water price has the potential to curb water consumption by incentivizing consumers to cut these nonessential and avoidable water uses. When water is scarce, these users are likely to be forced to consume less water than they would like. In this context, increasing prices would turn out to be ineffective as reductions in water consumption have already been driven by conditions.[3]

By comparison, in communities where the population is more concerned with environmental issues, price response may not be affected by water availability. When water is scarce, constraints coming with scarcity are less likely to be binding as water users exhibit lower preferences for consuming water. Accordingly, prices can still exert their power to incentivize consumers to cut water consumption.

3. Data and methodology

Meta-regression analysis (MRA) is used in the meta-analysis setting in order to pinpoint sources of variation in an effect size of interest, for instance, the price elasticity of water demand (Espey et al. 1997; Dalhuisen et al., 2003). In doing so, it may offer suggestions for improving primary data, study design, and model specifications and techniques. MRA also makes it possible to identify what causes study-to-study variations in empirical results by testing hypotheses about the relationships between the primary results and some moderating factors. In this paper, we use MRA for the last purpose and investigate whether the price elasticity of residential water demand is moderated by water scarcity.

3.1. Data collection

We conducted a systematic literature review to complement the sample of studies included in the meta-analysis of 51 studies by Dalhuisen et al. (2003). Following a literature screening process, 73 articles were added to the sample for a total of 124 papers obtained, providing 615 estimates from 31 countries and covering the period from 1963 to 2013 (for additional details, see Marzano et al., 2018). A list of the sampled studies and information coded in the meta-analysis is available upon request.

3.2. Variables, model and estimation technique

The dependent variable of our meta-regression model is represented by the water price elasticities (b_{ji}) reported in each study. We use two vectors of study-specific and location-specific characteristics as independent variables along with our water scarcity indicator (Kayaga et al., 2003). The resulting model is as follows:

$$b_{ji} = \beta_j + \alpha Water\ scarcity_j + \sum_{k=1}^{K} \gamma_k \mathrm{x}_{jik} + \sum_{s=1}^{S} \delta_s \mathrm{z}_{jis} + e_{ji} \quad j=1,2,\ldots,L;\ i=1,2,\ldots,N^j \quad (1)$$

where $\mathbf{x}_{ij}$ and $\mathbf{z}_{ij}$ encompass the K study-specific and S location-specific characteristics; the j indicates the L included studies and the subscript i refers to the N^j estimates reported in each study, respectively.

Equation (1) is consistent with the standard notation proposed by Stanley and Jarrell (1989): β_j is the baseline value of the water price elasticity, net of any study-specific and location-specific effect and it is indexed by j because we allow for heterogeneity across studies.

Applying conventional ordinary least squares (OLS) to the estimation of equation (1) can potentially lead to biased estimates because of the heteroskedasticity that arises from the difference in precision associated with price elasticity estimates. Equation (1) should ideally be estimated by adopting weighted least squares (WLS) and using inverse variances as weights in order to mitigate the risk of heteroskedasticity. Since most of the standard errors that are needed to compute the inverse variance matrix are missing in our dataset, we adopt an approach that is commonly followed in meta-regression analysis and proxy standard errors by using a monotonic transformation of the sample size relative to each observed price elasticity estimate (Horowitz and McConnell 2002; Stanley and Rosenberger 2009).

As in other previous meta-regressions, we control for a number of study characteristics that may explain variations in the estimates, including demand specification, data characteristics, estimation technique and location of the demand. The complete list of the independent variables used in the MRA and their descriptions are presented in Table I. As already mentioned, the operationalization of most of these variables is analogous to those of previous meta-analyses in the field (in particular that of Marzano et al., 2018). Moreover, we consider *Water scarcity* and *Environmental attitudes* as important additional factors.

Table I - List of independent variables in MRA and their description.

Panel A – Location-specific variables

Variable category (*baseline*)	Variable name	Variable description
Water scarcity indicator	Water scarcity	Water stress indicator (WSI)
Environmental attitudes indicator	Environmental attitudes	Based on responses drawn from the General Social Survey (1973-2013)
Socio-economic indicator	GDP per capita	Gross Domestic Product per capita
Water tariff scheme	IBR	=1 if customers are subjected to increasing-block rates (IBR)
(*flat rate*)	DBR	=1 if customers are subjected to decreasing-block rates (DBR)
Location	US	=1 if the location is in the United States
(*other parts of the world*)	Europe	=1 if the location is in Europe

Panel B – Demand specification variables

Variable category (*baseline*)	Variable name	Variable description
Type of price elasticity	Long-run	=1 if long-run elasticity is estimated
(*short-run elasticity*)	Segment	=1 if segment elasticity is estimated
Price measure	Marginal price	=1 if the marginal price is used as a price measure
(*average price*)	Shin price	=1 if the Shin price is used as a price measure
Conditioning variables	Number of variables	Number of conditioning variables
	Lagged consumption	=1 if lagged consumption included in demand specification
	Evapotranspiration rate	=1 if evapotranspiration rate included in demand specification
	Season	=1 if season is controlled for in the demand specification
	Household size	=1 if household size included in demand specification
	Population density	=1 if population density included in demand specification
	Income	=1 if income level included in demand specification
	Commercial uses	=1 if commercial use is controlled for in demand specification
	Temperature	=1 if temperature included in demand specification
	Rainfall	=1 if rainfall included in demand specification
	Difference variable	=1 if difference variable included in demand specification
Functional form	Log price	=1 if the specification is semi-logarithmic (x is logarithmic)
(*linear*)	Log consumption	=1 if the specification is semi-logarithmic (y is logarithmic)
	Double log	=1 if the specification is double logarithmic
	Flexible	=1 if the specification is flexible

Panel C – Data variables

Variable category (*baseline*)	Variable name	Variable description
Disaggregation overtime	Daily data	=1 if the primary study relies on daily data
(*annual data*)	Monthly data	=1 if the primary study relies on monthly data
Disaggregation overusers (*aggregate data*)	Household data	=1 if the primary study relies on household-level data
Data period	Summer data	=1 if the primary study uses summer data
(*cross-season data*)	Winter data	=1 if the primary study uses winter data
Data structure	Time-series data	=1 if the primary study relies on time-series data
(*cross-section data*)	Panel data	=1 if the primary study relies on panel data

Panel D – Methodology variables

Variable category (*baseline*)	Variable name	Variable description
Estimator	IV	=1 if the instrumental variable (IV) approach is used
(*OLS*)	2SLS	=1 if the two stages least squares (2SLS) approach is used
	3SLS	=1 if the three stages least squares (3SLS) approach is used
	DCC	=1 if the discrete-Continuous choice approach is used

Panel E – Publication variables

Variable category	Variable name	Variable description
Publication status	Published	=1 if the primary study is published
	Publication year	Publication year

We measure water scarcity at basin level through an index of the lack of sufficient fresh water for human consumption, namely, the Water Stress Indicator (WSI; Smakhtin et al. 2004) of the United Nations Environment Programme. WSI recognizes environmental water requirements (EWR) as an important parameter of the available freshwater. It approximates the total water availability from the mean annual runoff and measures EWR (i.e., water reserved for environmental purposes as a percentage of the long-term mean annual river runoff). The available water resources that incorporate EWR are computed after subtracting the annual water withdrawal for the industrial, agricultural and domestic sectors, as measured by the Food and Agriculture Organization and the International Water Management Institute.

Water scarcity is measured at the basin level with a 5-point scale from the minimum to the maximum WSI, that is, from not exploited to over-exploited basins. In order to obtain a country-level measure and a state-level measure for the United States, we project the basins over countries by employing the *AutoCAD 2015* software. The country-level *Water scarcity* indicator has then been built as a weighted average of the basin-level scarcities, using the size of the basins (or basin portions) as weights.

Valid data on environmental attitudes over time are very difficult to collect, given the number and geographical variety of locations considered in the meta-sample and the long time-span of the primary studies. In order to make the analysis feasible, we focus on a subsample that includes all of the price elasticity estimates obtained from studies using U.S. data. As far as the United States are concerned, reference has been made to data from the General Social Survey (GSS), a sociological survey administered by NORC at the University of Chicago, which has made information about the concerns, experiences, attitudes, and practices of U.S. households available since 1972. It is one of the most widely referenced surveys in the social sciences (Dietz et al., 1998; Oreopoulos and Salvanes, 2011).

For the purpose of our analysis, we use responses to one of the questions concerning the relative salience of problems faced by US society. Respondents were asked to indicate whether they think the United States is spending too much, too little, or about the right amount of money on improving and protecting the environment. The individual-level responses were coded using a three-level scale (3 for "too much", 2 for "about the right amount" and 1 for "too little"). Yearly data are available from 1972 to 2014 and a time-varying index of *Environmental attitudes* for each of the nine regional divisions used by the United States Census Bureau was built on the basis of these data. In order to make the index grow with the environmental attitudes, we subtract the regional indicator from 3.

3.3. Descriptive statistics

Figure 1 shows a funnel plot of the price elasticity estimates against the sample size. As expected, a large number of estimates are negative, although some positive elasticities are also reported (32 out of 615 observations). Publication bias is likely to be a significant issue in this literature. In this respect, the inclusion of some unpublished studies helps to mitigate the publication bias in the sample. Nevertheless, the funnel plot justifies the reliance on WLS to mitigate the heteroscedasticity that arises from differences in precision associated with the price elasticity estimates.

The average water price elasticity estimate has been found to be -0.40, with a standard deviation of 0.71. The most price-elastic estimated water demand reports a price elasticity of -7.47. These statistics are rather consistent with those reported by Dalhuisen et al. (2003), who found a sample mean of -0.41 and a standard deviation of 0.86. The rather price-inelastic nature of water demand is therefore confirmed by our enlarged survey.

Fig. 1 - Funnel plot of price elasticity over the sample size.

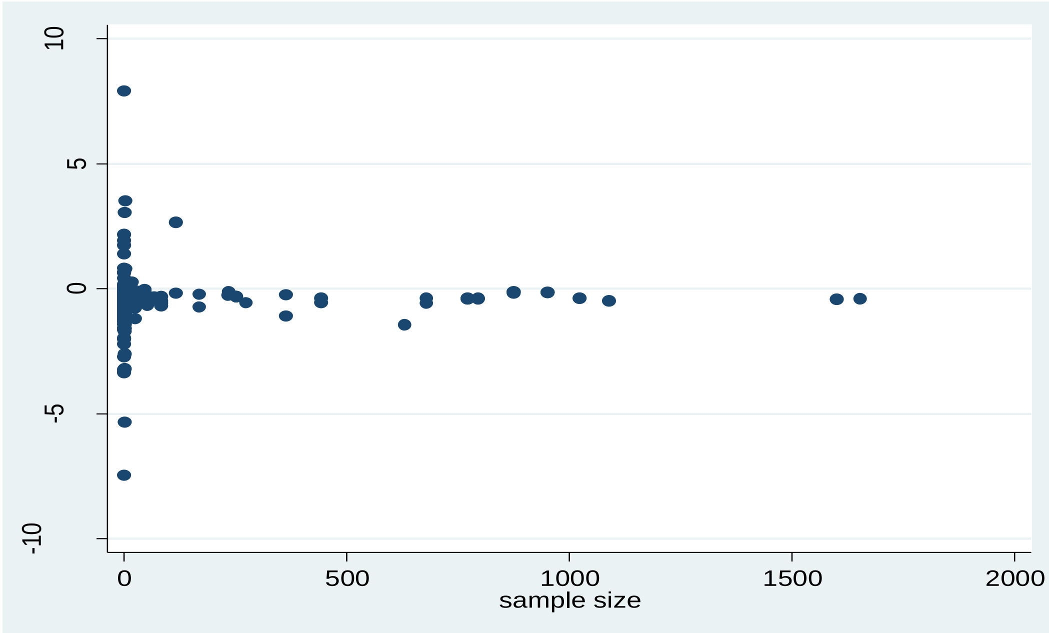

Table II reports the descriptive statistics of the independent variables included in the model described in equation (1). Since *Water scarcity* is a newly added independent variable, focusing on this variable is useful. We are able to measure *Water scarcity* over 601 observations. The mean value is 3.22 with a standard deviation of 1.50, which means that most of the studies collected data from moderately or highly water exploited areas (the variable ranges from 1 to 5).

Table II - Descriptive statistics.

Variable	Mean	S.D.	Max	Min
Water scarcity	3.220	1.497	5	1
Environmental attitudes	1.497	.1310	1.750	1.167
Long-run	.0992	.2992	1	0
Segment	.0425	.2019	1	0
Marginal price	.5213	.4999	1	0
Shin price	.0236	.1520	1	0
Number of variables	8.169	13.67	206	0
Lagged consumption	.1497	.3570	1	0
Evapotranspiration rate	.1035	.3049	1	0
Season	.1083	.3110	1	0
Household size	.4189	.4938	1	0
Population density	.0525	.2233	1	0
Income	.7898	.4078	1	0
Commercial uses	.0350	.1840	1	0

Temperature	.4350	.4962	1	0
Rainfall	.6035	.4896	1	0
Difference variable	.2299	.4211	1	0
Log price	.0252	.1568	1	0
Log consumption	.0173	.1306	1	0
Double log	.5423	.4986	1	0
Flexible	.0835	.2768	1	0
Daily data	.0835	.2768	1	0
Monthly data	.5260	.4997	1	0
Household data	.3669	.4823	1	0
Summer data	.0945	.2927	1	0
Winter data	.0677	.2515	1	0
Time-series data	.1480	.3554	1	0
Panel data	.6346	.4819	1	0
IV	.0457	.2089	1	0
2SLS	.0756	.2646	1	0
3SLS	.0094	.0968	1	0
DCC	.0205	.1417	1	0
Published	.8976	.3034	1	0
GDP per capita	25,086	9,929	59,065	762.1
IBR	.4031	.4909	1	0
DBR	.0567	.2314	1	0
US	.6520	.4767	1	0
Europe	.1748	.3801	1	0

4. Estimation results: The role of water scarcity

Table III presents the results of the model referring to equation (1). The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-sample. The relevant independent variable is the *Water scarcity* indicator.

The table reports the results of the WLS estimations obtained using the square root of the sample size as analytical weights (Stanley and Rosenberger, 2009). The studies included in the meta-sample report multiple estimates, depending on whether they use different subsamples, specifications, estimators, and so on. We correct the standard errors by clustering the estimates within studies because data dependence across estimates from the same study is a critical issue in the meta-regression.

The estimates referring to a specification that includes only study-level characteristics are reported in column (1) of Table III. The tariff scheme faced by customers, i.e. IBR and DBR, is considered in column (2). The location (United States and Europe) and GDP per capita are also added in column (3). The model reported in column (4) includes also country and time fixed effects.

Table III - Water scarcity effect.

	(1)	(2)	(3)	(4)
	Dependent variable: price elasticity			
Water scarcity	.0694	.0704	.2077**	.7047***
	(.0745)	(.0719)	(.0798)	(.1781)
GDP per capita			.0317***	.1192
			(.0108)	(.1104)
US			-.6206**	-5.118
			(.3117)	(4.126)
Europe			-.2716	
			(.3004)	
IBR		-.0236	-.0307	.7295*
		(.0423)	(.0410)	(.4164)
DBR		.4853	.4639*	.6839*
		(.2944)	(.3008)	(.4087)
Long-run	.3317	.3129	.3814	-.3043*
	(.2999)	(.2824)	(.2690)	(.1767)
Segment	-.2310	-.1747	.0671	-.1646
	(.5128)	(.5008)	(.4450)	(.1689)
Marginal price	.1087	.1023	.1078	.2896**
	(.1014)	(.0977)	(.0905)	(.1388)
Shin price	1.3150**	1.0918*	1.1023*	-.0162
	(.5129)	(.5579)	(.5630)	(.2502)
Number of variables	.0129***	.0131***	.0088***	-.0015
	(.0029)	(.0029)	(.0023)	(.0015)
Lagged consumption	-.3924	-.3729	-.4434*	.2207
	(.2932)	(.2764)	(.2647)	(.1771)
Evapotranspiration rate	.4969	.4223	.3033	.1169
	(.3108)	(.2854)	(.2605)	(.1070)
Season	.3636***	.3436***	.3397***	.4469***
	(.1234)	(.1183)	(.1178)	(.0315)

Household size	-.2177	-.1738	-.0875	.0079
	(.2655)	(.2518)	(.2253)	(.0876)
Population density	.4107	.3960	.2479	.3559
	(.3667)	(.3600)	(.4261)	(.6603)
Income	.1419	.0686	.3222	.0565
	(.2790)	(.2735)	(.2837)	(.1009)
Commercial uses	.9516***	.9001***	.9840***	.6708**
	(.3001)	(.2631)	(.2773)	(.2626)
Temperature	.4344	.3571	.3058	.0216
	(.2950)	(.2789)	(.2664)	(.1834)
Rainfall	-.0895	-.0378	-.1546	-.1637
	(.2765)	(.2490)	(.2048)	(.3729)
Difference variable	.5362*	.5248*	.5140	-.3194
	(.3139)	(.3120)	(.3216)	(.5760)
Log price	.9930	1.0350	1.2629*	-.0736
	(.7430)	(.7294)	(.7201)	(.1219)
Log consumption	.8410**	.8014*	.7568*	-.1082
	(.4123)	(.4440)	(.4121)	(.1482)
Double log	.0279	.0557	.2358	-.1012
	(.2457)	(.2429)	(.2580)	(.1928)
Flexible	.5348	.5108	.4022	-.0728
	(.4059)	(.3992)	(.3335)	(.0595)
Daily data	.7355	.8025*	1.0222*	-2.0575***
	(.4643)	(.4577)	(.5341)	(.7106)
Monthly data	-.2488	-.2450	-.0361	-.7731
	(.1813)	(.1789)	(.2301)	(.6464)
Household data	-.1140	-.1217	-.1614	.1680
	(.1714)	(.1631)	(.1676)	(.4784)
Summer data	-.1803	-.2020	-.2108	-.1412**
	(.1334)	(.1281)	(.1280)	(.0588)
Winter data	.1445	.1234	.1150	.1879**
	(.1260)	(.1204)	(.1235)	(.0825)
Time-series data	-.6738	-.6875	-1.2275*	-.7293
	(.4935)	(.4949)	(.6600)	(.7199)
Panel data	-.2591	-.2105	-.4832	-.3997
	(.2667)	(.2688)	(.3330)	(.7645)
IV	-1.7102**	-1.7094**	-1.7926**	-2.2764***
	(.7413)	(.7434)	(.7118)	(.5619)
2SLS	-.0699	-.0558	-.0215	-.2286
	(.1466)	(.1340)	(.1195)	(.2000)
3SLS	2.1300***	1.6554**	1.3370*	-.1201
	(.7953)	(.8212)	(.7104)	(.1295)
DCC	-1.5162***	-1.4635***	-1.5667***	-2.2682***
	(.4460)	(.4492)	(.4279)	(.5459)
Published	.0050	.0480	.0621	.0012
	(.2738)	(.2526)	(.2979)	(.3647)
Constant	-.9095	-.8659	-1.8895**	-6.0111*

	(.7395)	(.7378)	(.8801)	(3.5931)
Country fixed effects	No	No	No	Yes
Year fixed effects	No	No	No	Yes
Observations	581	582	572	529
Studies	114	114	112	108

Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively

The *Water scarcity* coefficient is positive across the four specifications and becomes statistically significant at the 5% and 1% levels in the two most comprehensive specifications. The magnitude of the effect is 0.208 in Model 3 and 0.705 in Model 4. This implies that customers living in locations that face a relatively higher degree of water stress are less sensitive to water prices.

The results open the question of whether the relatively feeble response to price measures of households in water-stressed areas is caused by the interaction between water scarcity and intrinsic motivations. This important and interesting issue is explored in more details in the next Section.

4.1. Water scarcity and intrinsic motivations to save water

The results reported in Tables III provide preliminary evidence on the role played by water scarcity in making water pricing less effective.

In order to gain an insight into how water scarcity drives the effectiveness of price measures for water conservation, we model intrinsic motivations as a moderator of water scarcity. In other words, we estimate a model that includes *Water scarcity*, the new independent variable *Environmental attitudes*, and their interaction term. We hypothesize that intrinsic motivation to save water can play a role in driving consumer responsiveness to price. In particular, we expect that water consumers who feel a moral obligation to save water simply out of a sense of public engagement and responsibility would be less sensitive to water pricing as they already exhibit lower preferences to water consumption. In addition, we expect that under conditions of water scarcity, water pricing will keep working in environmentally concerned communities, whereas it will be less effective in environmentally less concerned communities, since in the latter water users may already be consuming less water than they would like to. The working assumption we make is that communities in which people exhibit higher levels of attention to environmental issues are more likely to have intrinsic motivations to conserve water.

Table IV reports the results of the WLS estimations of a model that includes *Water scarcity* along with *Environmental attitudes*, as well as the interaction between the two and, depending on the specification, controls for study-specific characteristics, tariff schemes, and gross domestic product per capita.

Table IV - WLS estimates interacting water scarcity with environmental attitudes.

	(1)	(2)
Water scarcity	3.807***	4.077***
	(.8134)	(.7979)
Environmental attitudes	11.60***	11.70***
	(1.210)	(1.556)
Water scarcity*Environmental attitudes	-2.519***	-2.627***
	(.5320)	(.5095)
Location-specific controls	No	Yes
Study-specific controls	Yes	Yes
Constant	Yes	Yes
Observations	286	286
Studies	47	47

Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

All of the main variables are highly statistically significant. Once *Environmental attitudes* are taken into account, *Water scarcity* continues to display a positive sign, which means that under conditions of scarcity, when members of the community do not exhibit environmental attitudes, water demand is less responsive to changes in price. The same effect is found for *Environmental attitudes*. In areas where members of the community exhibit higher levels of environmental concern, when water is regularly available, the absolute values of the estimated price elasticities of water demand are lower.

The coefficient relative to the interaction term between *Water scarcity* and *Environmental attitudes* is negative and statistically significant at the 1% level in both columns (1) and (2); that is, intrinsic motivations, as measured by *Environmental attitudes*, may magnify the responses to price, but only in exploited water basins (the absolute value of price elasticity is higher).

In order to illustrate the magnitude of the impact of water scarcity in conjunction with environmental attitudes on the water price elasticity, we simulate water demand elasticity to prices, with all the independent variables, except *Water scarcity* and *Environmental attitudes*, set at their mean values. Table V shows that price elasticity decreases (in absolute value) going from mild (fourth quartile) to severe (first quartile) water scarcity when environmental attitudes are lower (fourth quartile), whereas it remains unaffected by scarcity when environmental attitudes are higher (first quartile).

Table V - Prediction of price elasticity at different levels of water scarcity and environmental attitudes.

Prediction of price elasticity	Lower environmental attitudes	Higher environmental attitudes
Mild scarcity (1)	-0.8815***	-0.2076
	(.2271)	(.1494)
Severe scarcity (2)	0.0065	-0.2471*
	(.3839)	(.1380)
Difference (1)-(2)	-0.8880***	0.0392
	(.2394)	(.1594)
Observations	286	286
Studies	47	47

5. Robustness checks

In this Section, we extend the preceding analysis with a battery of additional tests aimed at supporting the causal interpretation of the findings described in Section 4. Results are reported in Table VI.

As already mentioned in Section 4, data dependence across estimates from the same study is a critical issue in MRA. The results shown in Table IV have been obtained by clustering the observations within studies. An alternative approach applies panel data estimators to a panel that observes multiple estimates for single studies (Rosenberger and Loomis 2000; Stanley and Doucouliagos 2012). Column (1) of Table VI reports panel GLS estimates obtained using the square root of the sample size as analytical weights, as in model shown in Table IV. As expected, only standard errors differ from the results reported in Table IV. However, the coefficients preserve their significance (with *Water scarcity* and *Water scarcity*Environmental attitudes* switching their statistical significance from 1% to 5%).

Table VI – Robustness checks.

	Panel GLS	Trimmed price elasticities			MM-estimator	Post-1980	Post-1990	Post-2000	Arizona excluded	Texas excuded	California excluded	Scarcity dummy	Errors bootstrapped
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Water scarcity	4.077**	4.316***	4.006***	3.777***	0.718**	6.944***	4.401***	10.093***	5.225***	4.625***	4.179***	7.721**	4.077*
	(1.813)	(.5556)	(.5218)	(.5189)	(.3301)	(1.544)	(.5485)	(.0507)	(.8649)	(.6210)	(.9944)	(3.113)	(2.192)
Environmental attitudes	11.70***	12.03***	11.73***	11.54***	1.038	16.06***	11.59***	19.80***	13.47***	12.74***	11.99***	5.255***	11.70*
	(3.690)	(1.348)	(1.297)	(1.241)	(1.211)	(2.028)	(1.654)	(.1541)	(1.307)	(1.322)	(1.655)	(1.700)	(6.553)
Water scarcity	-2.627**	-2.763***	-2.596***	-2.474***	-.4516**	-4.516***	-2.834***	-6.4831***	-3.393***	-3.049***	-2.672***	-5.130**	-2.627*
*Environmental attitudes	(1.179)	(.3618)	(.3473)	(.3453)	(.2270)	(.9805)	(.3504)	(.0327)	(.5239)	(.4130)	(.6813)	(2.066)	(1.487)
Location-specific controls	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Study-specific controls	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	286	272	266	261	286	192	45	23	242	216	251	286	286
Studies	47	47	47	47	47	30	10	5	39	39	42	47	47

Standard errors are reported in parentheses. ** and *** denote significance at 5% and 1%, respectively.

A possible concern that may arise from the results shown in Section 4 is the potential influence of outliers, that is, observations for which price elasticity is positive or negative but too high to be considered reliable. In order to rule out the possibility that our estimates may be biased considerably by the presence of these outlier values, we re-estimate the model on different subsamples. Table VI reports the results of WLS estimations after having dropped positive price elasticities (Column 2), and after having dropped positive price elasticities and trimmed 1% (Column 3) and 2% (Column 4) of the observations on the left tail of the price elasticity distribution. We also run MM-estimation to further deal with the presence of outliers (Column 5).

The signs of the coefficients of the two main variables and their interaction are consistent with the previous analyses (though *Environmental attitudes* is only significant at the 20% level in column 5), thus ruling out the possibility of the results highlighted in Section 4 being driven by outliers.

Another concern with the results shown in Section 4 is related to the way in which we measure water scarcity. Computations performed by Smakhtin et al. (2004) to obtain the WSI are based on time series of monthly climate variables for the period from 1961 to 1990. Accordingly, in case of trends in water stress, the WSI would be unable to capture the actual water scarcity status for each basin along the entire time span covered by our meta-sample.

We address this issue by re-running estimations on three different data windows. Table VI reports the results of WLS estimations after having dropped observations from primary studies using data collected prior to 1980 (Columns 6), 1990 (Column 7) and 2000 (Column 8). In models shown in Columns (7) and (8) we do not control for study- and location-specific characteristics in order to deal with the very limited size of the two subsamples.

The magnitude of the effects is larger if compared with the results shown in Table IV. This actually seems to suggest the existence of a time trend in water stress that strengthens our empirical findings.

After having tested our results with respect to time trend in water stress, we turn to investigate whether our findings are robust to estimations that take into account the spatial polarization of our meta-sample. Many primary studies rely on common datasets, with the result that our meta-sample may include redundant observations as long as water scarcity, environmental attitudes and, to a lesser but still significant extent, price elasticity are concerned. Roughly 52% of observations in the U.S. studies relied on data collected in three states: Texas (24.5%), Arizona (15.4%), and California (12.2%).[4]

Table VI shows the results of WLS estimations after having excluded observations from studies that relied on data collected in Arizona (Column 9), Texas (Column 10), and California (Column 11). The results are similar in size and significance, suggesting that our findings are not driven by spatial polarization.

Another check, related to the linearity of the water scarcity indicator was also performed. We replicated the analysis reported in Table IV, but insulated extreme conditions. A new binary indicator is set to 1 if *Water scarcity* is at the maximum value (that is, 5). The results are illustrated in Column (12) of Table VI and are consistent with findings obtained with the core scarcity indicator but for a greater magnitude of scarcity effects. Finally, we rerun the WLS estimation by simultaneously bootstrapping the standard errors (Column 13).

These results confirm that prices are effective in reducing water consumption only as long as water scarcity is not a factor. Moreover, communities exhibiting higher levels of attention toward environmental issues show more stable responsiveness to pricing, whereas less environmentally friendly communities appear to be less sensitive to prices when scarcity is more severe.

6. Discussion and conclusions

Three major meta-analyses of residential water demand have been conducted to investigate the drivers behind systematic variations in price elasticity (Espey et al., 1997; Dalhuisen et al., 2003; Worthington and Hoffman, 2008; Marzano et al., 2018). Each had mainly limited the sources of variation to study-specific factors (such as data structure, water demand specification, and estimation technique) and to a lesser extent to location-specific antecedents (essentially gross domestic product per capita and the tariff structure in force). To better understand how individuals react to pricing mechanisms aimed at reaching water conservation goals, we also need to study the way economic incentives interact with geophysical characteristics. Our study takes on that challenge by investigating the relationship between location-specific water scarcity and water price elasticities reported in 124 primary studies published from 1964 to 2013. Specifically, relying on a meta-analysis setting, we investigated whether a richer representation of the contexts in which the water demand is located, as the effects of water scarcity and the environmental attitudes of the population, explain variations in estimates of water price elasticities.

Our study contributes to the literature on the economics of water conservation in two substantial ways. First, based on a study set that is substantially larger than the one of previous meta-analyses, we confirm that reported price elasticities are usually low in absolute value (that is, a relatively inelastic water demand is generally estimated). Our second contribution stems from considering water scarcity and the intrinsic motivation of citizens toward water conservation. Previous works pointed out that consumers characterized by positive attitudes toward environmental conservation consume significantly less water overall and especially across discretionary end-uses (Willis et al. 2011). At the same time, and despite the fact that water demand studies have frequently focused on areas characterized by water stress, the relevance of water scarcity to the effectiveness of water pricing mechanisms has remained mostly unexplored.

The relationship between intrinsic motivations toward conserving water and the price responsiveness of water demand is an empirical issue tackled here by means of our meta-sample. The results highlight that water scarcity and attitudes favoring environmental conservation may decrease the responsiveness of a focal population to water prices. At the same time, the results seem to indicate that a positive environmental attitude makes the price elasticity more stable as it does not significantly change with water scarcity. In other words, a substantial price increase in water-stressed areas may not motivate people to save more water as scarcity conditions or restrictions might have already forced their consumption below the desired level of usage. However, when scarcity affects communities characterized by environmental concern, since water consumption is lower, pricing mechanisms can still be effective. The detection of this moderating effect of environmental attitudes in residential water demand is a novel point of our study and it underscores the need to into account the specificities of local geography and society in estimating the responsiveness of water demand to changes in price.

We are aware of some limitations of this research. First, most of the reviewed primary studies are concentrated in the United States (and use data collected in a limited number of locations). Despite the large geographic, economic and regulatory diversity of this country, the analysis of DSM measures would benefit from a greater variety that could be achieved by focusing on other world regions. Second, it was possible to find a sufficient measure of environmental attitudes over the years only for the United States, and this restricts the sample for studying the intrinsic motivation to save water. Whether or not a more balanced geographic scope would confirm the role of intrinsic motivations is a question that we leave for future research, depending on the availability of data. Finally, despite these issues, we believe that our analysis helps to refine the extant empirical evidence on price elasticity determinants, and offers some intriguing insights into the understudied relationships between water scarcity, economic incentives, and the intrinsic motivations of consumers. These advances can help to improve the understanding of the factors that drive water consumer responsiveness to price signals. Therefore, they provide important indications for analysts, policymakers, and utility managers in the study and implementation of suitable management strategies for the water domain.

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Footnotes

[1] For instance, drought episodes may be accompanied by water restrictions and water rationing (Olmstead, 2010; Olmstead and Stavins, 2009). These may be voluntary or mandatory and limit the volume or time of use as well as certain water uses (such as irrigation, car washing, or swimming pool filling).

[2] Environmental attitudes can even harden water demand. However, as this is very location, time and household-specific, we may be able to observe only a reduction in average water price elasticity estimates.

[3] Conditions here may mean condition-driven policies, such as mandatory restrictions. Although we cannot directly control for the use of condition-driven policies, we assume that when water supply is scarce, they are likely to follow.

[4] Texas, Arizona and California are states where water scarcity is above average when compared with other U.S. locations.

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