Price elasticity of residential water demand and water scarcity

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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 that summarizes 615 estimates of the price elasticity of residential water demand, from 124 econometric studies. Large-sample studies have recently converged on the central result of previous meta-analyses, namely the low value of average price elasticity. However, owing to the availability of a broad dataset of studies, we single out location and community traits that boost or depress the price elasticity of residents. Our results reveal that water scarcity is a significant driver of price elasticity. More specifically, if water scarcity is harsh, residents' intrinsic motivations to save water crowd-out price measures.

Keywords: price elasticity, water demand, meta-analysis, water scarcity, environmental attitudes

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1. Introduction

Water managers and policy makers are struggling to meet water conservation goals, spurred by environmental and demographic challenges (e.g. climate change, deforestation, population growth, urbanization), mostly through command-and-control approaches and stopgap measures. At the same time, they are increasingly taking demand management strategies (DMSs) into consideration as a means to bring about water savings (Renwick & Green, 2000; Mansur & Olmstead, 2012).

Although price measures have been the first and most natural of the DMSs, their implementation is still hindered by a limited understanding of consumers' 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 are still open. Many authors have challenged the presumption of an elastic water demand (Barrett, 2004; Worthington & Hoffman, 2008) and, more generally, it remains unclear how water consumers react to water price depending on community- as well as individual-level characteristics.

In turn, the heterogeneity that affects price elasticity estimates prompted past systematic reviews that were conducted to identify and assess those factors that affect price elasticity the most. 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). However, the previous reviews, apart from considering household location, did not investigate in depth to what extent physical geography, in terms of water availability, has a moderating effect on consumers' responsiveness to water price changes. Water scarcity is a major global issue. Existing pressures on water resources will be exacerbated in the next future due to climate change and population growth in metropolitan areas. Moreover, water scarcity is the main issue to justify the recent great emphasis on water conservation goals around the world. Nonetheless, evidence on how consumers react to water pricing under different water scarcity scenarios is still scarce.

In this paper, we use a meta-analysis setting in order to investigate whether water price elasticity is contingent upon the local geographical context, in particular with respect to water scarcity. The analysis uses a meta-sample of primary studies, from 1964 to 2013, whose size - both in terms of papers and observations (single price elasticity estimates) - is more than double that of the one used in the last available meta-analysis. 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 the customers' responsiveness to water pricing. On the one hand, people can exhibit a greater willingness to save water when pricing is used to cope with the water scarcity that affects their community. On the other hand, scarcity may affect the interaction between response to economic incentives and intrinsic motivations to save water in differentiated (and unexpected) ways.

Greater scarcity implies stronger rivalry in consumption, since under a scarcity scenario each unit consumed reduces harshly what is available to others. 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 & Viladrich-Grau (2007) found that resource use falls with scarcity. By contrast, other scholars 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, i.e. the tendency to borrow from the future and ignore the potential for welfareenhancing collective action (Shah et al, 2012; Mani et al., 2013). Nevertheless, none of these studies has examined the moderating effect of scarcity on the effectiveness of monetary incentives.

We contribute to this debate 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. In addition, by relying on a subsample of studies using US data, we further analyze how environmental attitudes of communities shape this finding. We find that a high level of attention toward environmental issues damps the price elasticity in communities living in water stressed areas, while it magnifies the residents' response to price in less exploited areas. We establish our results controlling for a wide array of study- and location-specific factors, such as demand specification, data characteristics, price and tariff structures and estimation techniques adopted across studies.

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

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 motivation crowding

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, with Krause et al. (2003) suggesting a water price elasticity that is relatively sensitive to water scarcity regimes and Monteiro & Roseta-Palma (2011) instead claiming that water price elasticities are related to consumer preferences and do not vary according to scarcity.

Standard microeconomics predicts that the scarcity effect will supplement the price effect, where the latter entails a decrease in demand as a response to a price increase. Nevertheless, the result is based on the overly restrictive assumption that intrinsic motivation is an exogenously given constant and can be accordingly disregarded when investigating the effect of extrinsic motivators on the resource use. On the contrary, users can alter their preferences because of an external intervention, e.g. an increase in water price (see Frey, 1997) or alternatively maintain fixed preferences but experience a change in the perception of water use in the environment framing their water using actions, or in their own self-perception as decision makers (see Bénabou & Tirole, 2003).

Physical and environmental aspects related to water resource availability have been argued to influence the price elasticity of residential water demand through the elicitation of intrinsic motivations to save water. If intrinsic motivations substitute, or complement, price increases and other extrinsic consumption motivators, water price elasticities are likely to vary according to the water scarcity. Living in an area characterized by water stress can make water consumers more concerned about water conservation issues, both as individuals and members of the local community, and exposition to water-saving standards or other policies can make people engage in water conservation out of a sense of moral duty or public spiritedness. Nevertheless, the *motivation crowding* theory suggests that intrinsic motivations do not necessarily supplement the effects of extrinsic motivators, such as price increases. Intrinsic motivations may undermine or reinforce extrinsic ones, namely crowd them out or in (Frey & Jegen, 2001; Bowles & Polania-Reyes, 2012), thus altering the consumer's response to price in opposite ways.

Since economic incentives have increasingly earned favor in environmental policy as a means of preserving natural resources, a conspicuous number of studies have investigated motivation crowding effects triggered by economic incentives to encourage resource conservation goals. Rode et al. (2015) reviewed eighteen studies and identified evidence of motivation crowding-out and, to a lesser extent, crowding-in effects over a wide array of contexts including forest, water and fishery resources. A crowding-out effect is found when economic sanctions (Cardenas et al., 2000; Jack, 2009; d'Adda, 2011), rewards (Kerr et al., 2012; García-Amado et al., 2013), or both of them (Reichhuber et al., 2009; Velez et al. 2010; Greiner & Gregg, 2011; Travers et al., 2011) are adopted. On the other hand, crowding-in has been found to play a role by Sommerville et al. (2010), Van Hecken & Bastiaensen (2010) and Narloch et al. (2012).

A few studies have tried to open the black box in order to obtain a better understanding of the mechanisms behind the motivation crowding effect (Frey 1994; Frey & Jegen, 2001; Bénabou & Tirole, 2003; Ellingsen & Johannesson 2008; Festré & Garrouste, 2015). Overall, these studies suggest that crowding-out is more likely to occur if economic incentives are perceived as restrictive and controlling; if they reduce the degree of individual self-determination; if the setting in which they are introduced is one where norms of cooperation and reciprocity are in place; and if the decision frame is shifted toward a focus on economic reasoning, thereby reducing the influence of non-economic considerations. On the other hand, the psychological mechanisms behind the crowding-in effect rely on self-esteem from social recognition, improvement in people's general trust in regulating institutions and the assimilation of the normative signal of what constitutes desirable societal behavior conveyed by the regulating institution.

In our setting, intrinsic motivations can interact with price incentives and accordingly lead to differentiated responses in terms of water use. A scarcity scenario, by unleashing the intrinsic motivations to save water, could reinforce the residential customers' response to price increases aimed at conservation or could result in a weaker customers' response to prices, if an otherwise voluntary goodwill is perceived to be transformed into a market-like interaction. The crowding-out effect on price incentives may appear to be even stronger in the domain of water use than in other contexts because water services are fairly cheap in many countries. Large price increases may not represent a powerful incentive and may only leave room to a possible detrimental effect of intrinsic motivations.

3. Data and methodology

Meta-regression analysis (MRA) is often 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 on how to improve primary data, study design, and model specifications and techniques. Moreover, a MRA 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 price elasticity of residential water demand is moderated by water scarcity.

3.1. Data collection

The starting point of the present analysis has been the sample of 51 studies included in the meta-analysis by Dalhuisen et al. (2003). We complemented this dataset through two complementary search strategies. First, we consulted previous narrative review articles on residential water demand (e.g. Arbués et al., 2003; Worthington & Hoffman, 2008) and then a search by hand was made of the papers cited in these reviews. Second, we searched the following online databases: (1) Scopus, (2) ISI Web, (3) RepEc, (4) ScienceDirect, (5) Springer, (6) Wiley, (7) Social Science Research Network (SSRN), (8) the National Bureau of Economic Research (NBER), and (9) Centre for Economic Policy Research (CEPR). We compiled the simplest list of keywords, which included (1) "water", (2) "demand", and (3) "price elasticity", and conducted a Boolean search. We read all article abstracts and eliminated those not relevant to the topic. We developed a coding protocol and drew up a list of 352 articles. The studies were further filtered on the basis of two criteria. First, we selected only those articles that actually involved the estimation of water price elasticity through econometric techniques. Studies employing any other methodology to infer price elasticities were screened out. Second, only estimations of water demand by residential users were included. In several cases, this meant discriminating among various estimates reported in the same study, when only some of them used data pertaining to residential consumption. For the sake of completeness, 12 unpublished studies were also included in the sample, analogously to what done by Dalhuisen et al. (2003).

Upon completion of the literature screening process, 73 articles were added to the sample of 51 studies used by Dalhuisen et al. (2003). A total of 124 papers were obtained, including 615 estimates from 31 countries, covering the period from 1963 to 2013 (see Figure 1). A list of the sampled studies and information coded in the meta-analysis is available upon request. Two researchers read all of the papers to ensure a reliable coding of the effect size and all the meta-analysis explanatory variables.

[Insert Figure 1 about here]

3.2. Variables, model and estimation technique

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

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

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- 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 & McConnell 2002; Stanley & 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 Dalhuisen et al., 2003). Moreover, we consider *Water scarcity* as an important additional factor.[1]

[Insert Table I about here]

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. The geographical distribution of water scarcity, as measured by means of the WSI, is illustrated in Figure 2.

[Insert Figure 2 about here]

Water scarcity is measured at the basin level, through a 5-point scale, namely from the minimum to the maximum WSI, i.e. from not exploited to over-exploited basins. In order to

[1] This certainly represents the most relevant departure from the model specifications of the previous meta-analyses on water demand elasticity by Espey et al. (1997) and Dalhuisen et al. (2003), but it is not the only one. Specifically, the number of conditioning variables that the two mentioned studies did not take into account has also been included as an additional regressor.
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obtain a country-level measure and a state-level measure for the US, 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.

3.3. Descriptive statistics

Figure 3 shows a funnel plot of the price elasticity estimates against the sample size. Although, as expected, a large number of estimates are negative, some positive elasticities are also reported (32 out of 615 observations). Publication bias is not likely to be a significant issue in this literature. In this respect, it is worth recalling that we have included in the meta-sample unpublished studies. 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.

[Insert Figure 3 about here]

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 inelastic nature of the water demand is therefore confirmed also by our enlarged survey.

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, it is useful to focus on this variable. We are able to measure *Water scarcity* over 601 observations.[2] The

[2] Values are missing for primary studies that use cross-country data, due to the impossibility of univocally identifying the location.

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 exploited areas (the variable ranges from 1 to 5).

[Insert Table II about here]

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 & 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 that refer to a specification which 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 (US and Europe) and GDP per capita are also added in column (3).

[Insert Table III about here]

The *Water scarcity* coefficient is positive across the three specifications, and becomes statistically significant at the 5% level in the most comprehensive specification. The magnitude of the effect is 0.208. This implies that customers living in locations that face relatively higher degree of water stress are less sensitive to water prices. Simple simulations indicate that customers living in highly exploited areas (*Water scarcity* equal to 5) are practically insensitive to water price.

The result opens the question whether the feebler response to price measures of residents leaving in water stressed areas is caused by the interaction between water scarcity and intrinsic motivations (Cardenas et al., 2000; Jack, 2009; d'Adda, 2011). This important and interesting issue is explored in more details in the next Section.

4.1. Water scarcity and motivation crowding

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* (see *infra* for a description) and their interaction term. We hypothesize that as water stress becomes an issue in a given location, the intrinsic motivations to save water can become more stringent and displace economic incentives as a driving force. Water consumers, as members of a local community facing scarcity, could attempt to save water because they feel a moral obligation to do so or simply out of a sense of public engagement and responsibility. The elicitation of these intrinsic motivations could make the extrinsic ones, such as price measures, less relevant.

The working assumption we make is that communities that exhibit higher levels of attention to environmental issues are more likely to have intrinsic motivations to undertake actions to save water. Data on the 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 the price elasticity estimates obtained from studies using US 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 US residents available since 1972. It is one of the most influential and well-known surveys in social sciences and it is widely referred to in economics publications (Dietz et al., 1998; Oreopoulos & Salvanes, 2011).

For the purpose of our analysis, we use responses to one of the questions concerning the relative salience of problems faced by the US society. Respondents were asked to indicate whether they think the United States are 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. Figure 4 shows the overtime variation of *Environmental attitudes* in the United States as a whole.

[Insert Figure 4 about here]

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-level characteristics, tariff schemes and gross domestic product per capita.

[Insert Table IV about here]

The main variables are always highly statistically significant. Once *Environmental attitudes* is taken into account, *Water scarcity* displays a negative sign, which means that scarcity *per se* makes water demand more price-elastic. The same effect is found for *Environmental attitudes.* In the areas where communities exhibit higher levels of environmental concern, the absolute values of the price elasticities of the estimated water demand are higher.

The coefficient relative to the interaction term between *Water scarcity* and *Environmental attitudes* is positive 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 unexploited water basins (the absolute value of price elasticity increases). Where water scarcity is an issue, local communities that exhibit an environmentally friendly attitude are less likely to respond to economic incentives. The result supports our hypothesis that intrinsic motivations do not crowd-out economic incentives by themselves; crowding-out is triggered by water scarcity, a condition that makes water saving desirable for society. In other words, a strong yet general attitude of residents toward environment conservation in the community does not imply per se a clear awareness about water issues, or of moral and social reasons to save water. Nevertheless, the experience of water scarcity in one's own community may act as a focusing device for environmental attitudes. Only if water is visibly scarce in the basin, will economic incentives be perceived as inappropriate, given the moral and social nature of the challenge, and intrinsic motivations to save water may crowd-out the extrinsic motivation originating from the water price.

In order to illustrate the magnitude of the impact of water scarcity in conjunction with environmental attitudes on the price elasticity of the water demand, we make a back-of-the-envelope calculation by simulating water demand elasticity to prices, with all the independent variables, except *Water scarcity* and *Environmental attitudes,* being set at their mean values. When *Environmental attitudes* is set to its maximum and *Water scarcity* is increased by one standard deviation, the predicted price elasticity goes from -1.47 (statistically significant at the

1% level) to a value that is not statistically different from 0, thus pointing to a perfectly inelastic demand for water.

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.

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 & Loomis 2000; Stanley & Doucouliagos 2012). Table V reports panel GLS estimates obtained using the square root of the sample size as analytical weights, as in model shown in Table IV.

[Insert Table V about here]

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%).

A possible concern that may arise from the results shown in Section 4 is the potential influence of outliers, i.e. observations whose price elasticity is positive or negative and 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 1), and after having dropped positive price elasticities and trimmed 1% (column 2) and 2% (column 3) of the observations on the left tail of the price elasticity distribution.

[Insert Table VI about here]

The signs of the coefficients of the two main variables and their interaction are consistent with the previous analyses, 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 VII reports the results of WLS estimations after having dropped observations from primary studies using data collected prior to 1980 (columns 1-2), 1990 (column 3) and 2000 (column 4). In models shown in columns 3 and 4 we do not control for study- and location-specific characteristics in order to deal with the very limited size of the two subsamples.

[Insert Table VII about here]

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. Since data collection in the field of water economics is really tough, 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 relative to US studies used data collected in three states: Texas (24.5%), Arizona (15.4%) and California (12.2%).

[Insert Table VIII about here]

Table VIII shows the results of WLS estimations after having excluded observations from studies that relied on data collected in Arizona (column 1), Texas (column 2) and California (column 3). The results are similar in size and significance, which suggest that our findings are not driven by spatial polarization.

A final check, related to the linearity of the water scarcity indicator, has been performed. We replicate the Table IV analyses, but this time we insulate most extreme water stress conditions. A new water scarcity indicator is considered, that is, a binary variable set equal to 1 if *Water scarcity* is at its maximum value, i.e. 5. The results are illustrated in Table IX. They confirm the findings obtained with the core scarcity indicator, but for a greater magnitude of scarcity effects.

[Insert Table IX about here]

Using the binary version of the water scarcity measure, we can plot the predictions of the model and show how price elasticity estimates vary in the two scarcity scenarios, i.e. high and low levels of water scarcity, over different degrees of environmental concerns (see Figure 5).

[Insert Figure 5 about here]

As the graph shows, prices are only effective in reducing water consumption as long as water scarcity does not represent an issue and communities exhibit high levels of attention toward environmental issues. However, when water scarcity does become a problem, the intrinsic motivations to save water stemming from a great environmental attitude make consumers of these communities much less sensitive (i.e. crowd-out) to economic solicitations represented by water prices.

6. Discussion and conclusions

Two meta-analyses on residential water demand had been conducted so far in order to investigate the drivers behind systematic variations in price elasticity (Espey et al., 1997; Dalhuisen et al., 2003). Both of them had mainly limited the sources of variation to study-specific factors (such as data structure, water demand specification, estimation technique, etc.) and to a lesser extent to location-specific antecedents (essentially gross domestic product per capita and the tariff structure in force). However, in order 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 different location-specific 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. More specifically, by 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.

In doing so, we contribute to the literature on the economics of water conservation in two substantial ways. First, based on an information set that is substantially larger than the one of previous meta-analyses, we confirm that reported price elasticities are usually low in absolute value (i.e. an inelastic water demand is generally estimated). But beside this general result, and more importantly, our second contribution stems from considering water scarcity as a factor that elicits the intrinsic motivation of citizens toward water conservation. Previous works pointed out that consumers characterized by positive attitudes toward environment conservation consume significantly less water overall, and especially across discretionary end-uses (Willis et al. 2011).

At the same time, and in spite of the fact that water demand studies have frequently focused on areas characterized by water stress, the effect of water scarcity on the effectiveness of water pricing mechanisms has remained unexplored.

The relationship between intrinsic motivations toward conserving water and the price responsiveness of water demand is an empirical issue that we tackled here by means of our meta-sample. The results highlight that water scarcity and the citizens' attention toward environment conservation increase the responsiveness of a focal population to water prices. However, at the same time, they also indicate that a positive environmental attitude depresses the price elasticity of those who live in a water stressed area. In other words, a substantial price increase in these areas may not convince people to save water and may even lead to erode their intrinsic motivations to do so. The detection of this crowding-out effect in the residential water demand is an important point of novelty of the present study and it underlines the necessity of taking into account the specificities of local geography and society for analysts, policymakers and those who implement DMSs.

We are aware of some limitations of the present study. First, it has been possible to find a sufficiently good measure of environmental attitudes over the years only for the United States, and this has led the sample to being restricted when the motivation crowding effect has been studied. 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. Second, most of the reviewed primary studies are concentrated in the US. Despite the large geographic, economic and regulatory diversity of this country, the analysis of DSM measures could benefit from a greater variation that could be achieved by focusing on other world regions. Finally, in spite of 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 relationship between economic incentives, water scarcity and the intrinsic motivations of consumers. Both these advances can help to improve the understanding of the factors that drive water consumers' responsiveness to price signals. Therefore, they provide important indications for analysts, policy makers and utility managers in the study and implementation of the most suitable DMSs for the water domain.

Figures

Fig. 1 - Distribution of the sampled water demand studies over time.

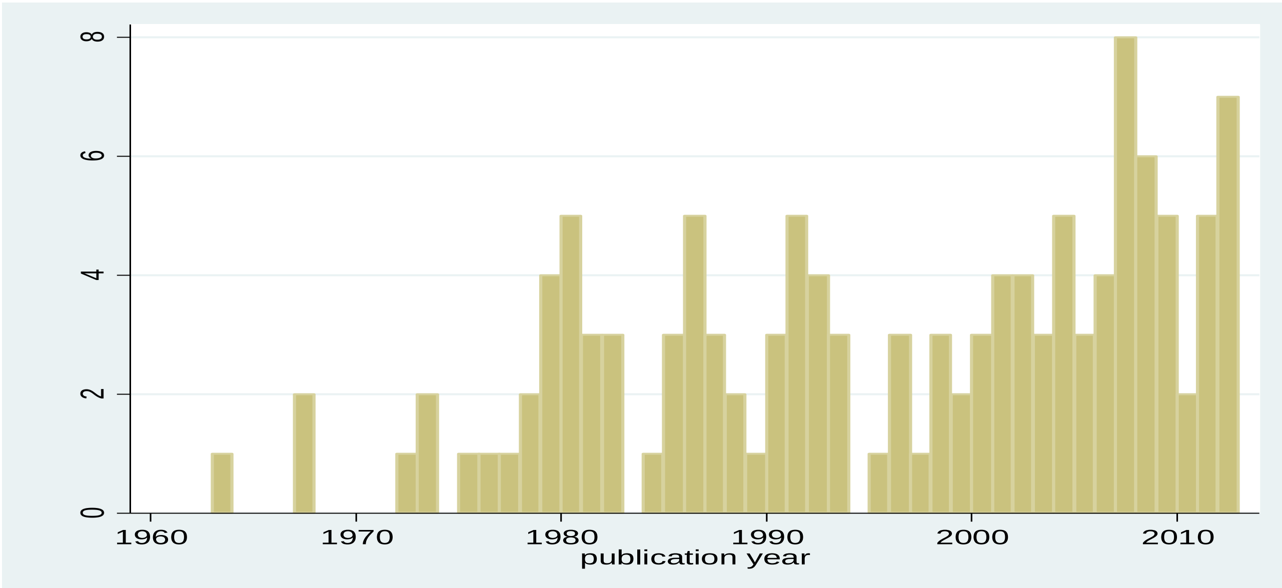


Fig. 2 - Water Stress Indicator in the major water basins throughout the world.

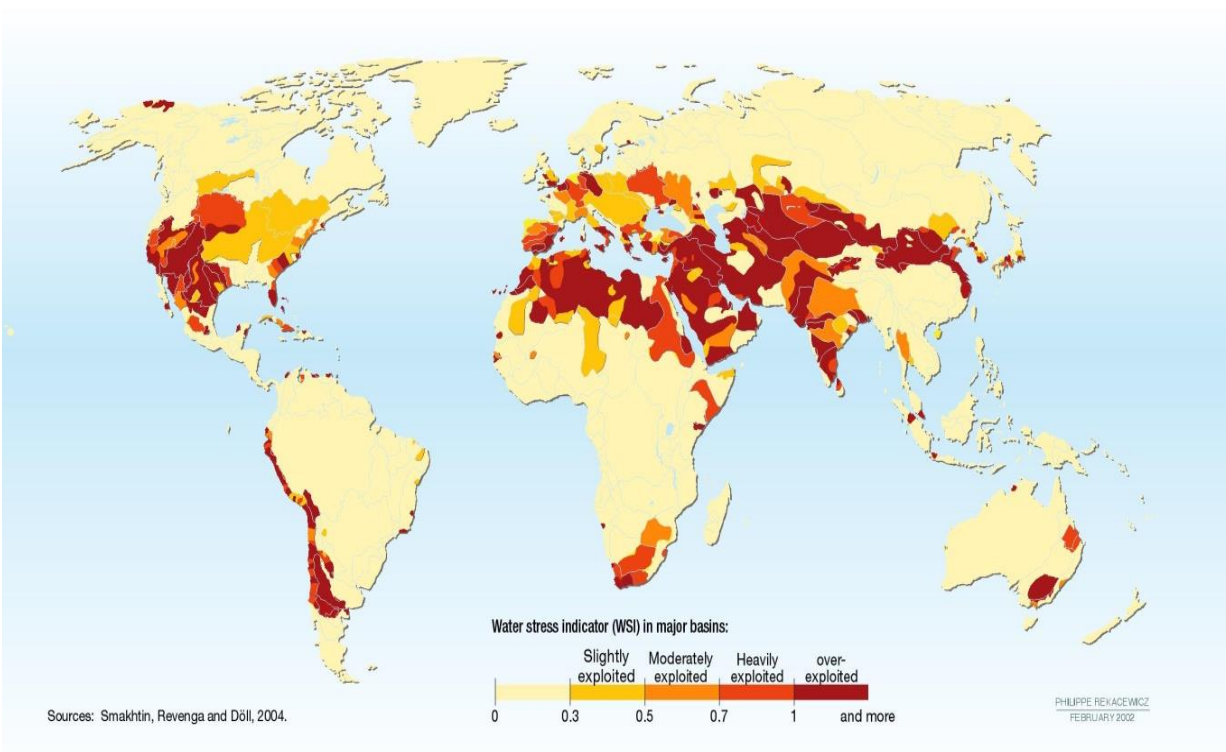


Fig. 3 - Funnel plot of price elasticity over the sample size.

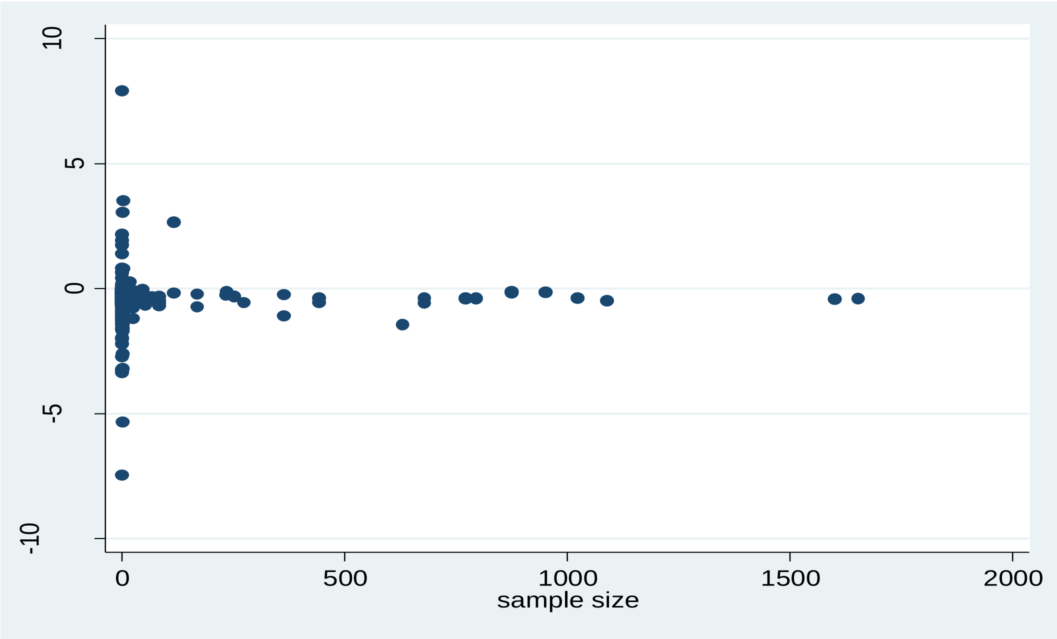


Fig. 4 – Environmental attitudes over time in the United States.

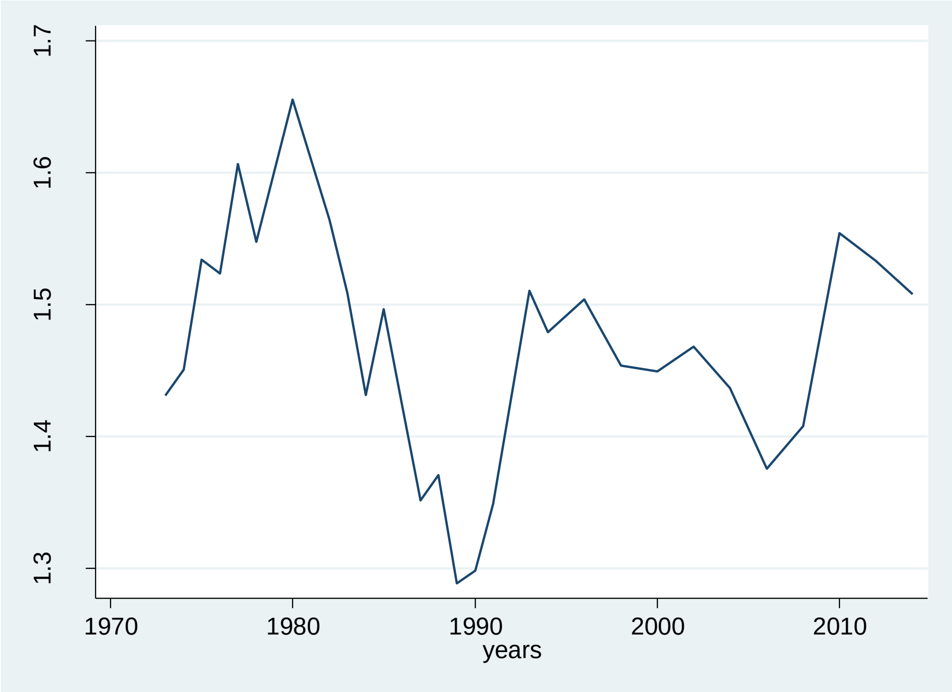
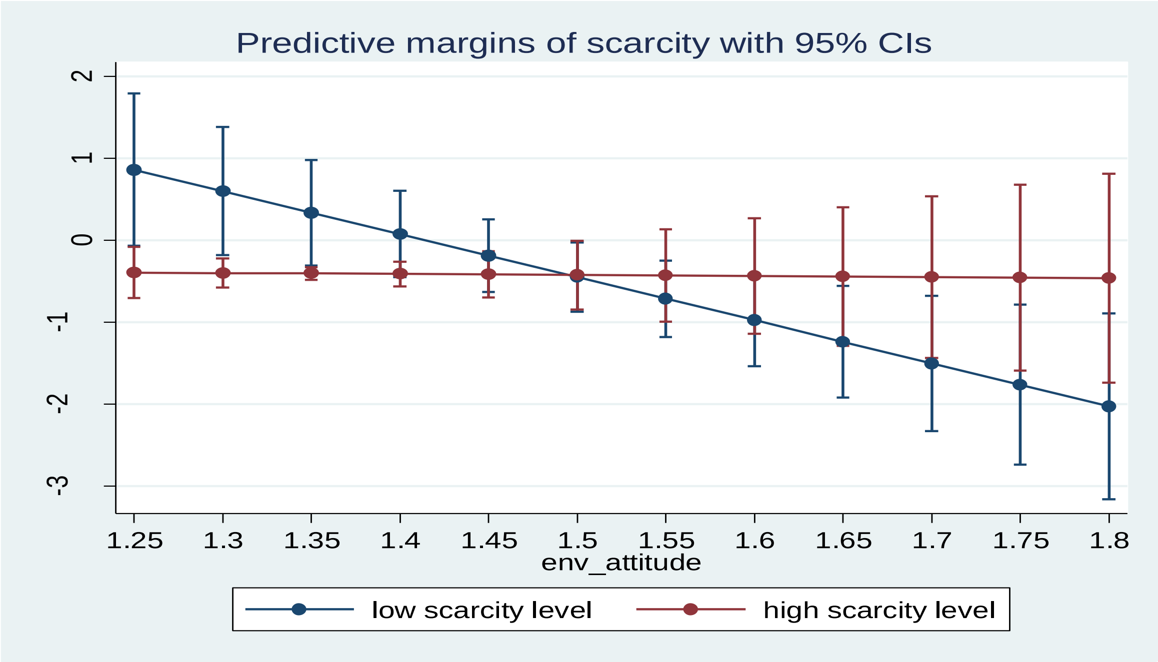


Fig. 5 – Predictive margins of scarcity moderated by environmental attitudes.



Tables

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

continued…

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

Table II - Descriptive statistics.

Variable	Mean	Sd	Max	Min
Water scarcity	3.220	1.497	5	1
Environmental attitudes	1.504	.1310	1.833	1.250
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

Table III - Water scarcity effect.

.

	(1)	(2)	(3)
	Dependent variable: price elasticity		
Water scarcity	.0694	.0704	.2077**
	(.0745)	(.0719)	(.0798)
GDP per capita			.0317***
			(.0108)
US			-.6206**
			(.3117)
Europe			-.2716
			(.3004)
IBR		-.0236	-.0307
		(.0423)	(.0410)
DBR		.4853	.4639*
		(.2944)	(.3008)
Long-run	.3317	.3129	.3814
	(.2999)	(.2824)	(.2690)
Segment	-.2310	-.1747	.0671
	(.5128)	(.5008)	(.4450)
Marginal price	.1087	.1023	.1078
	(.1014)	(.0977)	(.0905)
Shin price	1.3150**	1.0918*	1.1023*
	(.5129)	(.5579)	(.5630)
Number of variables	.0129***	.0131***	.0088***
	(.0029)	(.0029)	(.0023)
Lagged consumption	-.3924	-.3729	-.4434*
	(.2932)	(.2764)	(.2647)
Evapotranspiration rate	.4969	.4223	.3033
	(.3108)	(.2854)	(.2605)
Season	.3636***	.3436***	.3397***
	(.1234)	(.1183)	(.1178)
Household size	-.2177	-.1738	-.0875
	(.2655)	(.2518)	(.2253)
Population density	.4107	.3960	.2479
	(.3667)	(.3600)	(.4261)
Income	.1419	.0686	.3222
	(.2790)	(.2735)	(.2837)
Commercial uses	.9516***	.9001***	.9840***
	(.3001)	(.2631)	(.2773)
Temperature	.4344	.3571	.3058
	(.2950)	(.2789)	(.2664)
Rainfall	-.0895	-.0378	-.1546
	(.2765)	(.2490)	(.2048)

continued…

	(1)	(2)	(3)
Difference variable	.5362*	.5248*	.5140
	(.3139)	(.3120)	(.3216)
Log price	.9930	1.0350	1.2629*
	(.7430)	(.7294)	(.7201)
Log consumption	.8410**	.8014*	.7568*
	(.4123)	(.4440)	(.4121)
Double log	.0279	.0557	.2358
	(.2457)	(.2429)	(.2580)
Flexible	.5348	.5108	.4022
	(.4059)	(.3992)	(.3335)
Daily data	.7355	.8025*	1.0222*
	(.4643)	(.4577)	(.5341)
Monthly data	-.2488	-.2450	-.0361
	(.1813)	(.1789)	(.2301)
Household data	-.1140	-.1217	-.1614
	(.1714)	(.1631)	(.1676)
Summer data	-.1803	-.2020	-.2108
	(.1334)	(.1281)	(.1280)
Winter data	.1445	.1234	.1150
	(.1260)	(.1204)	(.1235)
Time-series data	-.6738	-.6875	-1.2275*
	(.4935)	(.4949)	(.6600)
Panel data	-.2591	-.2105	-.4832
	(.2667)	(.2688)	(.3330)
IV	-1.7102**	-1.7094**	-1.7926**
	(.7413)	(.7434)	(.7118)
2SLS	-.0699	-.0558	-.0215
	(.1466)	(.1340)	(.1195)
3SLS	2.1300***	1.6554**	1.3370*
	(.7953)	(.8212)	(.7104)
DCC	-1.5162***	-1.4635***	-1.5667***
	(.4460)	(.4492)	(.4279)
Published	.0050	.0480	.0621
	(.2738)	(.2526)	(.2979)
Constant	-.9095	-.8659	-1.8895**
	(.7395)	(.7378)	(.8801)
Observations	581	582	572
Studies	114	114	112

The table reports the results of the WLS obtained using the square root of the sample size as analytical weights. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-analysis. Depending on the specification, the models control for scarcity, study-level characteristics, tariff schemes, location of the water demand and gross domestic product per capita. Standard errors (clustered by studies) are reported in parentheses. *,**, and *** denote significance at 10%, 5% and 1%, respectively

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

	(1)	(2)
Water scarcity	-3.749***	-3.803***
	(.7860)	(.7388)
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

The table reports the results of WLS obtained using the square root of the sample size as analytical weights. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-analysis. Depending on the specifications, the models control for study-level characteristics, tariff schemes and gross domestic product per capita. Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

Table V - Panel GLS estimates interacting water scarcity with environmental attitudes.

	(1)	(2)
Water scarcity	-3.749**	-3.803**
	(1.741)	(1.746)
Environmental attitudes	-11.60***	-11.70***
	(3.661)	(3.690)
Water scarcity*Environmental attitudes	2.519***	2.627**
	(1.171)	(1.179)
Location-specific controls	No	Yes
Study-specific controls	Yes	Yes
Constant	Yes	Yes
Observations	286	286
Studies	47	47

The table reports the results of panel GLS obtained using the square root of the sample size as analytical weights. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-sample. Depending on the specifications, the models control for study-level characteristics, tariff schemes and gross domestic product per capita. Standard errors are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

Table VI - WLS estimates after having trimmed the extreme price elasticity values.

	(1)	(2)	(3)
Water scarcity	-3.974***	-3.781***	-3.645***
	(.5379)	(.5264)	(.5234)
Environmental attitudes	-12.03***	-11.73***	-11.54***
	(1.348)	(1.297)	(1.241)
Water scarcity*Environmental attitudes	2.763***	2.596***	2.474***
	(.3618)	(.3473)	(.3453)
Location-specific controls	Yes	Yes	Yes
Study-specific controls	Yes	Yes	Yes
Constant	Yes	Yes	Yes
Observations	272	266	261
Studies	47	47	47

The table reports the results of the weighted least squares (WLS) estimations obtained using the square root of the sample size as analytical weights. The regression shown in column (1) was run after having dropped the positive price elasticities; the regression in column (2) was run after having dropped the positive price elasticities and trimmed 1% of the observations on the left tail of the price elasticity distribution; the regression in column (3) was run after having dropped the positive price elasticities and trimmed 2% of the observations on the left tail of the price elasticity distribution. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-analysis. In all of the specifications, the models control for study-level and location-specific characteristics. Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

Table VII - WLS estimates using only studies with data collected after 1980.

	Post-1980		Post-1990	Post-2000
	(1)	(2)	(3)	(4)
Water scarcity	-6.241***	-6.605***	-4.100***	-9.357***
	(1.461)	(1.400)	(.5027)	(.0476)
Environmental attitudes	-15.20***	-16.06***	-11.59***	-19.80***
	(2.070)	(2.028)	(1.654)	(.1541)
Water scarcity*Environmental attitudes	4.250***	4.516***	2.834***	6.4831***
	(1.026)	(.9805)	(.3504)	(.0327)
Location-specific controls	No	Yes	No	No
Study-specific controls	Yes	Yes	No	No
Constant	Yes	Yes	Yes	Yes
Observations	192	192	45	23
Studies	30	30	10	5

The table reports the results of WLS obtained using the square root of the sample size as analytical weights. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-analysis. Depending on the specifications, the models control for study-level characteristics, tariff schemes and gross domestic product per capita. Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

Table VIII - WLS estimates dropping observations relative to more represented states.

	Arizona excluded	Texas excluded	California excluded
	(1)	(2)	(3)
Water scarcity	-4.954***	-4.522***	-3.838***
	(.7187)	(.6322)	(1.060)
Environmental attitudes	-13.47***	-12.74***	-11.99***
	(1.307)	(1.322)	(1.655)
Water scarcity*Environmental attitudes	3.393***	3.049***	2.672***
	(.5239)	(.4130)	(.6813)
Location-specific controls	Yes	Yes	Yes
Study-specific controls	Yes	Yes	Yes
Constant	Yes	Yes	Yes
Observations	242	216	251
Studies	39	39	42

The table reports the results of WLS obtained using the square root of the sample size as analytical weights. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-analysis. In all of the specifications, the models control for study-level characteristics, tariff schemes and gross domestic product per capita. Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

Table IX - WLS estimates using a dummy variable to measure scarcity.

	(1)	(2)
Water scarcity	-7.611***	-7.668**
	(2.593)	(3.097)
Environmental attitudes	-4.924***	-5.255***
	(1.348)	(1.700)
Water scarcity*Environmental attitudes	5.117***	5.130**
	(1.755)	(2.066)
Location-specific controls	No	Yes
Study-specific controls	Yes	Yes
Constant	Yes	Yes
Observations	286	286
Studies	47	47

The table reports the results of WLS obtained using the square root of the sample size as analytical weights. The dependent variable is the price elasticity reported in each estimate of each primary study included in the meta-analysis. Scarcity is measured using a dummy variable set equal to 1 for areas characterized by the highest level of water exploitation, according to the WSI. Depending on the specification, the models control for study-level and location-specific characteristics. Standard errors (clustered by studies) are reported in parentheses. *, **, and *** denote significance at 10%, 5% and 1%, respectively.

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