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# Determinants of the price response to residential water tariffs: Meta-analysis and beyond

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ABSTRACT

Meta-analyses synthesise available data on a phenomenon to get a broader understanding of its determinants. This work proposes a two-step methodology. 1) Based on a broad dataset of residential water demand studies, it builds a meta-regression model to estimate mean and standard deviation of price elasticity of residential water demand. 2) The resulting meta-model serves as a basis for implementing an approach that directly simulates the range of price elasticities resulting from policy-relevant combinations of its determinants. This simulation approach is validated using the available dataset. Despite evidence of low average price elasticity, the scenarios simulated using our meta-regression estimates show that increasing block rate tariffs are associated with higher price elasticity, and stresses the importance of using state-of-the-art methodologies when evaluating the price response. This completes other methodological insights obtained from the meta-analysis itself. Policy implications on the use of pricing to bring about water savings are discussed.



## 1. Introduction

Pricing is an appealing instrument to bring about water savings. The increasing emphasis of water policies on "putting the right price tag on water" (EC, 2012) and the shift to discontinuous pricing structures such as increasing block rates (IBRs) are two instances of current attitudes toward water pricing, which is aimed at promoting water conservation while maintaining equity and affordability (Rogers et al., 2002). This paper offers a synthesis on the existing evidence on the response of households to water prices by means of a meta-analysis. Contrary to previous studies on this topic, it also goes beyond by validating an exploratory simulation approach based on meta-analysis results. It then uses this approach to produce supplementary insights regarding some of the determinants of price response such as tariff structure. There are three main motivations for this effort.

First, severe droughts have recently hit a few US states and Latin American countries, and episodes of water shortage have occurred in Asia and also in Europe (Kummu et al., 2010; MacDonald, 2010). The debate on water use efficiency and the implementation of conservation policies has grown in scope and urgency as a result, as it has been extended to more geographical locations, including countries traditionally unaffected by large-scale water shortage events.

Second, and despite the ongoing debate involving policymakers, scientists and citizens on water conservation, policy remedies are unclear. On the one hand, demand management has emerged as a cost-effective complement or even as an alternative to supply-side solutions – the expansion of infrastructure capacity. On the other hand, command-and-control policies such as use restrictions or mandatory retrofit programs seem to be less cost-effective than price measures in the short and long run (Olmstead and Stavins, 2009; Escriva-Bou et al., 2015).

Finally, despite an extensive literature focusing on estimating the price elasticity of water demand, it remains unclear whether, to what extent and under which circumstances, consumers respond

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**Data availability**

*We are committed to make available along with the paper the dataset we developed and we used to carry out the analyses here reported*

*Dataset name* Meta-dataset on water demand

Short description "Meta-dataset on water demand" is a dataset that contains hand collected data about primary studies published from 1963 to 2013 which have tried to estimate the residential water demand and water price elasticity in particular. Observations are at single estimate level. They are 615, coming from 124 primary studies. The research paper describes the variables included in the dataset with the relative sources. The dataset is useful for replication purposes. Moreover, making it available would facilitate accumulation and processing of future empirical evidence

Developers The dataset was assembled by building on data made available by Dalhuisen et al. (2003), which comprise 51 primary studies published before 2001. Some additional 73 primary studies were added to obtain the final dataset.

*The final dataset was assembled by Riccardo Marzano (riccardo.marzano@polimi.it) with contributions from Silvia Padula*

Form of repository Spreadsheet

Size of archive 188 KB

Software required MS Office

*Access form* (here the link to the repository where the dataset will be available)

to changes in the price of water. This is particularly true when pricing structures move from traditional two-part tariffs with a uniform, steady and generally low uniform rate to more complex pricing structures, such as increasing or decreasing block rates, drought prices, or time-of-use prices.

In the absence of a definitive, consensus answer emerging on these issues, syntheses are helpful. Several reviews have been written on the estimation of the residential water demand, including Arbués et al. (2003), Grafton et al. (2011), House-Peters and Chang (2011), Nauges and Whittington (2009), Worthington and Hoffman (2008). Over the years, literature has enlarged the spectrum of adopted methodologies. This, in turn, has led to a better handling of the uncertainties and nonlinearities that exist between water consumption and its determinants, and more generally, a better understanding of the complex spatial and temporal patterns of water usage.

A quantitative alternative to reviews are meta-analysis methods, which have become widely used in the economics and management literature (Stanley and Jarrell, 1989; Moeltner et al., 2007; Geyskens et al., 2009; Nelson and Kennedy, 2009; Tunçel and Hammitt, 2014). Meta-analysis allows statistical evidence from different studies to be combined to obtain a quantitative and systematic overview on the effect size of interest, and to derive common summary statistics with corresponding confidence intervals. This technique generally results in increased statistical power, and can result in improved parameter significance and accuracy compared to primary studies alone. This allows the researcher to provide more reliable within-sample predicted values of the dependent variable under a particular set of conditions. Moreover, a meta-regression analysis (MRA) makes it possible to test hypotheses about the relationships between the effect size of interest and some primary study-specific factors in order to identify what causes study-to-study variations in empirical results. In doing so, it may offer suggestions on how to improve primary data, study design, and model specifications and techniques.

Three previous meta-analyses provided summary statistics of water price elasticity. Espey et al. (1997) used a sample of 124 price elasticity estimates from 24 journal articles produced between 1967 and 1993. They reported a mean water price elasticity of −0.51. Dalhuisen et al. (2003) extended the previous sample and ran their meta-regression on 296 estimates taken from 51 studies produced between 1963 and 2001. They obtained a sample mean of −0.41. Sebri (2014) focused on 100 studies produced between 2002 and 2012 and obtained a mean value of −0.365. The bulk of the literature indicates that water demand is price inelastic, and few studies have reported price elasticity estimates larger than −0.25, i.e. smaller in absolute value (see Renwick and Archibald, 1998; Martínez-Espiñera and Nauges, 2004).

Nevertheless, these systematic reviews highlighted the high heterogeneity that affects water demand studies. They rely on data at different disaggregation levels, both over time (annual, monthly and daily data) and over space (household versus municipality or country data). They focus on either average or marginal prices. They make use of very diverse demand specifications and estimation techniques.

This work goes beyond the meta-analysis on residential water price elasticity recently carried out by Sebri (2014) in two respects. First, this analysis is based on a sample of 124 primary studies produced from 1964 to 2013, whose size in terms of studies is considerably larger than that of the one used in previous available meta-analyses. In fact, it considers a publication time span that bridges both Dalhuisen et al. (2003) and Sebri (2014). We estimate a meta-regression model that is robust to heteroskedasticity stemming from the variation in precision of sampled price elasticity estimates. As in previous meta-analyses on the same topic, our specifications include a wide array of study- and location-specific factors (data characteristics, methodologies, socio-economic factors, tariff structures, and so on). Our specifications are also robust to the presence of outlier values.

Second, in this paper, we go beyond the meta-regression model by formulating, validating and demonstrating a simulation approach that extrapolates the meta-analysis model to evaluate the plausible range of price elasticity estimates for set values of some of the meta-model specifications, which we call scenarios. We simulate scenarios aimed at directly answering policy-relevant questions where a meta-analysis can only tell whether the question is worth asking. For instance, the meta-analysis shows that using DCC models (discrete-continuous choice; Hewitt and Hanemann, 1995; Olmstead et al., 2007; Olmstead, 2009) to analyze the price response with increasing block rates (IBR) leads to values of price elasticity that are greater in a statistical sense. Yet, this is not a direct quantification of how price elasticities are affected by 1) tariff structure and 2) methodological choices. The simulation approach we propose provides this quantification. Besides, it makes it possible to explore the impact of combined impacts of several variables, whereas a meta-regression model can only yield insights on the influence of individual variables.

The rest of the paper is organised as follows. Section 2 reviews the studies conducted on water demand. Section 3 presents the data and describes the methodology for the meta-analysis. Section 3 reports the results of our meta-regression model. Then, Section 4