Water Resources and Economics 46 (2024) 100243

Contents lists available at ScienceDirect

Water Resources and Economics

journal homepage: www.elsevier.com/locate/wre

Exploring gender differences in residential water demand

Roberto Balado-Naves *, Sara Suárez-Fernández

University of Oviedo, Department of Economics, Avda. Del Cristo, s/n, 33006 Oviedo, Spain

A R T I C L E I N F O

Handling Editor: Erik Ansink

JEL classification:
Q21
Q25
D12
D90

Keywords:
Residential water demand
Stone geary
Oaxaca-blinder
Gender differences

A B S T R A C T

Residential water demand has been extensively studied, with the impact of various household characteristics on consumption well-documented. However, the specific effect of gender on household consumption remains insufficiently identified due to the predominant focus on mixed-gender households in previous research. In this paper, we aim to address this gap by examining gender differences in water consumption specifically within single-gender households. To accomplish this, we analyze data from 275 households equipped with individual meters in the city of Gijón, Spain, between 2017 and 2021. Our approach involves two main steps: first, the estimation of a Stone-Geary demand function for water consumption for both women and men single-gender households, and second, employ the Oaxaca-Blinder decomposition to examine gender differences based on the previous estimations. Our findings reveal that women's households consume significantly more water compared to men's households. Additionally, we observe that the demand for water is more inelastic among women, and their level of conditional use threshold is higher than that of men. Importantly, we find that these differences can be primarily attributed to distinct factors such as family composition, housing characteristics, and bill information between genders.

1. Introduction

Two-thirds of the global population lives under conditions of severe water scarcity [1], and about 2 billion people live in areas suffering from water stress [2]. While the causes of water depletion are various [3], this excessive demand for water is unsustainable [4]. With that in mind, managing water scarcity is a current challenge for human development and for achieving the UN Sustainable Development Goals [5].

A valuable tool for managing residential water consumption are water demand-side management policies (DSM), which can be classified into pricing and non-pricing strategies [6]. Since water is a basic need, pricing strategies are controversial [7] and in turn, non-pricing strategies are growing exponentially. Among non-pricing policies, nudges have emerged as one of the most promising strategies since their first applications in the water field by Ferraro et al. [8], Ferraro and Miranda [9], and Ferraro and Price [10]. Since nudges tend to be more effective when messages are personalized [11,12], improving the available knowledge on consumer profiles and their consumption patterns will be crucial for efficient policymaking.

For instance, gender is an observable characteristic of individuals which seems to be associated with different environmental attitudes. Some studies have argued that women are more environmentally concerned than men (e.g., Ref. [13–15]), as well as more prone to engage in more eco-friendly behaviors [16]. Furthermore, gender also seems to be strongly related to water-conservation

* Corresponding author.
E-mail addresses: baladoroberto@uniovi.es (R. Balado-Naves), suarezfsara@uniovi.es (S. Suárez-Fernández).

https://doi.org/10.1016/j.wre.2024.100243
Received 2 August 2023; Received in revised form 5 April 2024; Accepted 11 April 2024
Available online 16 April 2024
2212-4284/

habits. As Addo et al. [17] explain, women have a strong concern for the efficiency and sustainability of water interventions and the management of water resources, which make them more susceptible to water-saving policies.

Besides, gender is also strongly correlated with other variables. Significant differences can be found in wage (e.g., Ref. [18–20]), education and health levels (e.g., Ref. [21,22]), or risk, social, and competitiveness preferences [23], among others. All these differences may create variances in water consumption patterns across single-gender households, or households where most water consumption decisions are made by one gender.[1]

Recent studies have also stressed the importance of cognitive and information biases in rational decision-making. More precisely, imperfect information regarding water prices, consumption levels, and the moral cost of water has been shown to lead to inefficient water demand [24–26]. This problem is especially true when water consumers face multinomial, non-linear, and block prices, given the complexity of their tariffs [26–28]. Considering that previous research has shown strong evidence in favor of women being more risk averse than men [23], we should expect women to be more likely to have better information regarding water services.

Regarding specific literature on gender and water demand, previous analyses have found mixed results regarding the role of gender [6]. For instance, Mu et al. [29] concluded that women in developing countries increase water consumption due to a lower opportunity cost in water collection. Considering aggregate regional data, Reynaud [30] found that water consumption is higher for women, a likely consequence of them devoting more time to water-consuming household chores [31,32]. Horsburgh et al. [33] carried out a study on water usage in public restrooms and concluded that women consume almost twice as much water on average than men. They argue that this is likely due to differences in restroom device availability (urinals consume less water than toilets), as well as hygiene habits. On the contrary, Karlis et al. [34] and Davies et al. [15] found that women consume less water than men on average. In this sense, women tend to adopt more water-saving habits as compared to men [31], and they seem to be more environmentally concerned regarding water stress risks [35,36].

To sum up, the existing literature seems to point towards higher consumption among women due to better hygiene habits and more intensive household chores, but not due to water-wasting practices. However, these studies can be imprecise in identifying consumption differences across genders. On the one hand, estimations of the impact of gender will not be accurate when the data only contains information regarding the gender of one member from households with multiple members, as in Kayaga et al. [37], Davies et al. [15] or Tong et al. [32]. On the other hand, when information on the gender composition of each household (or region) is available, as in Reynaud [30], Garcia et al. [38] and Grespan et al. [39], standard regression methods cannot identify to what extent the differences in water demand patterns of men and women are due to differences in observable characteristics, such as age or income, or due to differences in responsiveness to changes in these characteristics. This implies an important loss of information for accurate and effective policymaking.

In this paper, we aimed to tackle these shortcomings in the existing literature. To that end, we studied water consumption patterns and their determinants in mixed- and single-gender households. Similar to our approach is that of Räty and Carlsson-Kanyama [40], who studied single households to calculate the total energy use for men and women in four European countries (Germany, Norway, Greece and Sweden), finding significant differences between genders. In this line, we estimated a water demand function for the pooled sample (considering both mixed- and single-gender households, that is, all households in the sample) and for each gender, computing elasticities and calculating the level of conditional water use thresholds separately.

One of our main contributions is applying the Oaxaca-Blinder method [41,42], which has been applied to many subjects outside of the original field of labor economics, in the context of residential water demand. The closest applications might be Lin et al. [43] who studied race and energy poverty, and Liu et al. [44], who measure urban-rural difference of dietary water footprint, but neither of these assess gender differences in residential water consumption. By using the Oaxaca-Blinder decomposition method, we assessed the proportion of differences that can be explained by varying socioeconomic and housing characteristics, as well as by differences in environmental awareness and the quality of information on water billing data. We also estimated the proportion of water consumption differences not explained by these variables. In all cases, the reference point is the estimated water demand function for the pooled sample of mixed- and single-gender households to minimize potential selection bias.

The remainder of the paper is structured as follows: Section 2 summarizes the adopted methodology and the data employed in the econometric analysis. Section 3 shows the main results of the study, and Section 4 presents the conclusions and policy implications.

2. Materials and methods

This work seeks to analyze the impact of differences in characteristics between men and women on their water consumption levels. To that end, we considered the Oaxaca-Blinder decomposition of differences in water demand functions of single-gender households. Therefore, we started by analyzing the chosen residential water demand model.

2.1. Stone-Geary residential water demand with a three-block increasing rate schedule

As it is widely used in recent residential water demand literature, we focused on the Stone-Geary water demand function (e.g., Ref. [45–52]). The advantages of this function include the presence of a positive water consumption volume independent of prices and disposable income, and non-constant price and income elasticities [49]. Furthermore, it presents a parsimonious-enough form to

[1] Grønhøj and Ölander [94] found that household members tend to specialize in different sub-activities according to their gender.

estimate accurate price elasticities without excessive parametrization of the model and yields time- and season-dependent elasticities coherent with previous evidence on water demand [45]. The bimonthly water demand of a given household can be read as:

$$C_{it} = \alpha_0 + \sum_{j=1}^{K} \alpha_j X_{ij} + \sum_{z=1}^{Z-1} \rho_Z D_{iz} + \sum_{t=1}^{T-1} \psi_t D_t + \beta Inc/Price_{it} + \varepsilon_{it} \tag{1}$$

where α_0 is an arbitrary constant term; α_j are the marginal effects associated with the j exogenous and time-constant household characteristics X_{ij}, which aim to capture cross-sectional heterogeneity; ρ_Z are the marginal effects of the $Z-1$ district fixed effects D_{iz},[2]; ψ_t are the marginal effects of the $T-1$ time fixed effects D_t; β is the marginal effect of bimonthly household income corrected by Nordin's difference [53] and divided by marginal water prices $Inc/Price_{it}$ or $Inc/Price_{it}$; and ε_{it} is the idiosyncratic error term.

Assuming perfect information and rational decisions by water consumers under a three-block increasing rate schedule requires the following computation of household income divided by marginal prices [27,54]:

$$Inc/Price = \begin{cases} \dfrac{I-F}{p_1} \; if\ C \le b_1 \\ \dfrac{I-F+(P_2-P_1)b_1}{P_2} \; if\ b_1 < C \le b_2 \\ \dfrac{I-F+(P_3-P_1)b_1+(P_3-P_2)b_2}{P_3} \; \text{if } C > b_2 \end{cases} \tag{2}$$

where I is the bimonthly household income prior to correction; F is the value of fixed water charges; P_s is the price of each cubic meter of water within the s consumption block; and b_s are the upper limits of the consumption blocks. The part concerning the weighted difference between the marginal price and the price of previous blocks of consumption, $(P_z - P_s)b_s$, where $z > s$, is the Nordin's difference variable which captures the income effect associated with switching blocks of consumption.

From (1), the conditional water use threshold equals:

$$\gamma_{it} = \frac{1}{1-\beta}\left(\alpha_0 + \sum_{j}^{K} \alpha_j X_{ij} + \sum_{t}^{T-1} \psi_t D_t\right) \tag{3}$$

which represents the amount of water unresponsive to price changes and is a linear combination of exogenous regressors such as the available technology, the state of house ownership, or the price of water-consuming durable goods during the time period of the estimation, among others [45].

On the other hand, price/income elasticities equal:

$$\eta_{it}^{p} = -\eta_{it}^{I} = -\beta \frac{Inc/Price_{it}}{C_{it}} \tag{4}$$

which increase in income and decrease in prices and water consumption.

Since prices follow an increasing rate schedule, estimation of (1) with standard OLS will produce an upward bias in estimates [55, 56]. Similar to Pérez-Urdiales et al. [57], we followed the control function procedure [58]. This procedure is like the 2SLS estimation, wherein we first estimate the following equation:

$$Inc/Price_{it} = \delta_0 + \sum_{j=1}^{K} \delta_j X_{ij} + \sum_{t=1}^{T-1} \lambda_t D_t + \varphi_1 P_{1t-1} + \varphi_2 P_{1t-2} + \omega_{it} \tag{5}$$

and include its estimated residuals in (1) to control for endogenous regressors.

Previous works have chosen as instruments the base prices from the most common consumption blocks [55,56]. Since most households from our data sample are in the first block,[3] the chosen instrumental variables are the first- and second-time lags of the base price for the first consumption block, P_{1t}, so we could test for instrument exogeneity. See Appendix A for results of the control function estimation.

2.2. The Oaxaca-Blinder decomposition of water consumption differences

To examine differences in estimated water demands between single-gender households of men and women, we considered the Oaxaca-Blinder decomposition [41,42], which is widely used in the field of Labor Economics to analyze wage differentials between

[2] Since most of the household characteristics have been compiled in a one-time survey, they do not present time variability. Therefore, we cannot estimate equation (1) employing the standard fixed-effects estimator, and we try to alleviate this problem by including district effects (the water supplier divides the municipality of Gijón into 11 different districts for supply and administrative purposes. These go from rural to urban districts, and downtown to suburban areas).

[3] More than 89 % of the observations present consumption levels equal to or lower than 30 m^3.

subsamples. In our context, the goal is not to close the gap between women and men, as it is in the context of wage discrimination, but rather to reduce water consumption in both genders. Here, we focus on understanding the consumption behaviors of each gender, without necessarily aiming to equalize them or "close the gap". Here, the analysis is centered on examining how disparities between household characteristics impact the specific consumption patterns of each gender, delving deeper into the understanding of these dynamics.

This method decomposes statistically significant differences into *explained* and *unexplained* parts. The first part shows the effect of differences in household characteristics across genders, while the latter shows the effect of differences in gender responsiveness towards regressors and the constant term (usually regarded as discrimination in Labor Economics literature).

In the context of water demand, the explained part examines the statistical significance of differences in household socioeconomic characteristics (such as real income or education), housing characteristics (outdoor amenities or efficient appliances) and water-related household information (good water habits or billing information) on differences in consumption across single-gender households. Both significance and direction of the differences will be determined by the joint interaction between the size of the average difference in variables, and the statistical significance and sign of the estimated marginal effects. For instance, if the estimated marginal effect of income divided by the marginal price (*Inc/Price*) on residential water consumption would be significant and positive, and the average *Inc/Price* in men households would be sufficiently larger than that of women households, then we expect that if men consume more water than women, is partially because having higher *Inc/Price*.

$$E(C_W) - E(C_M) = \underbrace{\sum_{j=1}^{K} \widehat{\alpha}_j^* \left[E(X_{jW}) - E(X_{jM})\right] + \widehat{\beta}^* \left[E(Inc/Price_W) - E(Income/Price_M)\right]}_{Explained\ Part}$$
$$+ \underbrace{\widehat{\alpha}_{0W} - \widehat{\alpha}_{0M} + \sum_{j=1}^{K}\left[\left(\widehat{\alpha}_{jW} - \widehat{\alpha}_j^*\right)E(X_{jW}) + \sum_{j=1}^{K}\left(\widehat{\alpha}_j^* - \widehat{\alpha}_{jM}\right)E(X_{jM})\right]}_{Unexplained\ Part} + \underbrace{(\widehat{\beta}_W - \widehat{\beta}^*)E(Inc/Price_W) + (\widehat{\beta}^* - \widehat{\beta}_M)E(Inc/Price_M)}_{Unexplained\ Part} \tag{6}$$

where $\widehat{\alpha_j^*}$ and $\widehat{\beta^*}$ are the estimated parameters from the water demand function of the entire sample of households with a dummy regressor identifying those households having only men.[4] This method follows Neumark [59], Oaxaca and Ransom [60], and Jann [61], who advocated for the use of no-discriminating parameters to avoid the *index number problem* that arises when reference parameters are chosen on an ad hoc basis [42]. Therefore, we assume that the least biased coefficients of equation (1) are those obtained from a linear regression over a representative sample including both single- and mixed-gender households. Following Neumark [59], we assume that the no-discriminating marginal utility of a randomly selected member in a given household should be equal to the average marginal utility at that household, weighted by gender composition. Additionally, since we included several dummy variables, we followed the procedure of Gardeazabal and Ugidos [62] of imposing a normalizing restriction on their coefficients to keep the unexplained part of water consumption differences neutral from the choice of the reference group.

2.3. Data and variables

The database used in this study is one of its main contributing elements (see Tables 1 and 2 for a comprehensive description of variables and their summary statistics). The municipality of Gijón, situated on the northern coast of Spain, boasts a population exceeding 270,000 residents, covers an area of 181.7 square kilometers. Moreover, Gijon is characterized by a mild climatic regime, with average temperatures of 14 °C. Furthermore, its population is spread across both rural and urban areas, with nearly 11 % of inhabitants residing in non-urban regions.[5]

In the 2030 scenario in Asturias, it is expected a reduction in hydric resources of 6 % on average and 9 % in years with lower runoff. Additionally, the possible occurrence of drought episodes combined with the potential effects of climate change could further decrease these water resources available. At the same time, municipal urban demand could rise by more than 7 %, stemming from both the projected population growth and a significant estimated increase in industrial urban demand due to the development of certain industrial areas [63,64].

Information regarding real bimonthly water consumption and its marginal prices was obtained from the water supplier in Gijón, public company EMA (*Empresa Municipal de Agua*). Water consumption levels correspond to meter reading information. Household socioeconomic and housing characteristics were obtained from a survey conducted in Gijón between December 2020 and April 2021. Due to the pandemic, the survey was conducted using a mixed collection system, which involved sending out letters with an enclosed questionnaire to households. To ensure representation of the population, both mail and online submissions were considered, given that Gijón has a population with 26 % of elderly people.

Since consumption and billing data are collected at an aggregate scale for each household, we do not have information regarding the levels of consumption associated with each household member. Consequently, previous studies have been imprecise at identifying gender patterns in water consumption due to an imputation of residential water use to the gender of head of the household or the

[4] Subscripts W and M in variables of equation (6) refer to information from women and men households, respectively.
[5] For further information, please visit https://observa.gijon.es/pages/inicio.

Table 1
Variables and their definitions.

Variable	Name	Definition
Consumption	Water consumption	Household bimonthly consumption in each billing period (m^3)
Income	Net household Income	Estimated household bimonthly income, net of fixed charges and Nordin's D (€)
Price	Water marginal price	Price of the last block of water consumption reached (€)
Inc/Price	Real income	Net income divided by water marginal prices (Inc/Price)
Men	Household of men	Dummy variable: 1 if all the members of a household are men
Members	Household members	Number persons living in the surveyed household
Senior	Share of seniors	Proportion of household members older than 65 (%)
Minor	Share of minors	Proportion of household members younger than 18 (%)
Employed	Share of employed	Proportion of household members employed or self-employed (%)
College	Share of educated	Proportion of household members with tertiary education or higher (%)
Old house	Old house	Dummy variable: 1 if residence is over 40 years old
Garden	Owns a garden	Dummy variable: 1 if residence owns a garden
Pool	Owns a swimming pool	Dummy variable: 1 if residence owns a swimming pool
Dishwasher	Owning a dishwasher	Dummy variable: 1 if residence has a dishwasher
Efficient devices	Index of efficient devices	Share of water-saving devices in residence
Efficient appliances	Index of efficient appliance	Share of water and energy-saving appliances in residence
Water habits	Good water-saving habits	Dummy variable: 1 if the respondent declares having more than 6 of the 13 habits
Campaign	Aware of water saving campaign	Dummy variable: 1 if remembers a water-saving campaign implemented during the last five years
Bill unaware	Unaware of the total water bill	Dummy variable: 1 if the respondent does not know the value of their last water bill or does not answer
Bill underestimation	Degree of underestimation of the total water bill	Percentage of underestimation of their last total water bill (%)
Zero	Zero consumption	Dummy variable: 1 if the household has not consumed any water in the period

Table 2
Main statistics.

Variable	All households (N = 26,860)		Women (N = 4463)		Men (N = 2856)	
	Mean	SD	Mean	SD	Mean	SD
Consumption	17.277	17.323	11.716	11.104	10.591	9.233
Income	4153.341	1454.294	3124.469	1223.338	3167.318	1213.744
Price	1.036	0.170	1.018	0.143	1.012	0.131
Inc/Price	4209.737	2145.271	3289.177	2165.822	3355.967	2177.026
Men	0.106	0.308	–	–	–	–
Members	2.441	1.069	1.407	0.700	1.250	0.455
Seniors	28.825	41.162	46.083	46.476	32.353	45.73
Minors	10.585	18.357	2.188	9.883	3.105	12.512
Employed	43.301	37.174	38.151	44.209	48.699	47.551
College	17.975	29.963	18.635	35.940	18.487	36.883
Old house	0.484	0.500	0.669	0.471	0.536	0.499
Garden	0.199	0.399	0.082	0.274	0.118	0.322
Pool	0.044	0.204	0.025	0.156	0.019	0.139
Dishwasher	0.617	0.486	0.417	0.493	0.452	0.498
Efficient devices	21.123	24.897	13.085	19.03	20.579	23.829
Efficient appliances	55.549	42.087	43.726	40.154	51.278	38.822
Water habits	0.890	0.313	0.877	0.328	0.922	0.269
Campaign	0.404	0.491	0.340	0.474	0.472	0.499
Bill unaware	0.255	0.436	0.294	0.456	0.250	0.433
Bill underestimation	3.006	12.767	1.468	9.034	5.401	18.403
Zero	0.017	0.129	0.023	0.149	0.029	0.169

Notes: "All households" refers to the pooled sample of households, while "Women" refers to the subsample of single-gender women's households, and "Men" to the subsample of single-gender men's households.

survey respondent. We avoid this issue by focusing on a subsample of single-gender households, defined as families in which all members are either men or women, and both genders do not coexist in the home, regardless of their age.

The database covers 1068 households with individual water meters, from which 275 are single-gender households,[6] spanning 28 periods between 2017 and the first six months of 2021. Since not all users were connected to the water network throughout the 28 periods, we have an unbalanced panel data with 169 households of women (4463 observations) and 106 households of men (2856 observations).

The stratification of the sample into single- and mixed-gender households may introduce a selection bias issue. In this context, heterogenous attributes across single- and mixed-gender households could be linked to the likelihood of being selected during the data collection process (refer to Table A1 in Appendix A), similar to the labor market where the observed wages are indirectly influenced by the characteristics determining the probability of being employed [65,66]. Neglecting this problem results in biased estimators and statistically significant regressors that may not truly be determinants of the dependent variable [67].

To address this issue, we adopt the approach outlined by Heckman [67,68] and derive the inverse of the Mill's ratio from a probit estimation on the probability of belonging to the subsample of single-gender households (refer to Section 3.1 for the results). Estimating the inverse of the Mill's ratio requires including exogenous instrumental variables that are correlated with the probability of belonging to a single-gender household but not with residential consumption levels. Therefore, we included the share of members with Spanish nationality (*National*), a dummy variable indicating whether the surveyed household was residing in a shared apartment or not (*Shared*), and another dummy variable taking the value of 1 if the household had been living at their current residence for 5 years or less (*Newcomer*). The main statistics of these variables across the entire sample, as well as for single-gender and mixed-gender households, are presented in Appendix A.

Water consumption and household income are aggregated bimonthly, as water consumption is billed in two-month periods, resulting in six bimonthly periods per year. Regarding income, household earnings were categorized into six different intervals of net monthly household income, ranging from €0–500 to €2701–3700. Following Carlevaro et al. [69] and Binet et al. [27] in the context of water demand, we obtained a continuous variable for household disposable income, conducting a regression analysis to explain income, considering household and socioeconomic household characteristics.[7] After this, fixed water charges and the Nordin's difference are subtracted from the estimated household income, as shown in equation (2).

The water prices in Gijón follow an increasing block tariff (IBT).[8] Accordingly, marginal prices follow a three-block increasing

[6] Initially, 6800 households were contacted, but the response rate was around 30 %. Moreover, some households were excluded due to too much missing information or statistical aberrations. The complete database contains 1068 single- and mixed-gender households.

[7] Regression results can be found in Appendix B. The procedure is outlined by Manski and Tamer [95] and Van Doorslaer and Jones [96]. We considered the entire sample of households. We included the total surface of the house in quadratic meters as an additional regressor, whose main statistics are shown in Appendix A.

[8] Most households are only affected by the first block, where prices were 1.02234 €/m^3 before January 2020, and 1.05347 €/m^3 from January 2020 onwards. Further information can be found at BOPA núm. 300 de 30-xii-2014, núm. 248 de 27-xii-2019, núm. 175 de 29-VII-2014.

structure, increasing by cubic meters of water consumption (see Appendix E). Furthermore, the application of a retroactive variable part of the regional water sanitation tax leads to increases in the net marginal prices of each consumption block. Therefore, Nordin's difference is more sensitive to changes between consumption blocks, and price misperceptions penalize consumer welfare to a larger extent. However, given that most of the sample households are in the first consumption block throughout time (almost 90 % of the observations are in this block, with only 7 % reaching the second one), the impact of the regional water sanitation tax is expected to be minimal. Fixed charges range between €7.52–33.50, with a mean of €16.63 and a mode of €16.92.[9] These charges are a combination of a service fee for the maintenance and repair of the water supply network, which increase with water meter size, and a constant regional water sanitation tax aimed at fostering efficient water consumption and funding the preservation of water resources in Asturias[10].

The remaining explanatory variables of the Stone-Geary demand function are commonly found in the previous literature (e.g., Ref. [6,70]).

- **Household socioeconomic characteristics:** We considered several factors related to household socioeconomic characteristics. These included the number of household members (*Members*), age composition considering the proportion of *Seniors* and *Minors*, employment status (*Employed*), and education level (*College*), which comprised the proportion of employed individuals, and the proportion with tertiary education or higher.
- **Housing characteristics:** We included dummy variables to account for houses older than 30 years (*Old house*), houses with outdoor amenities (*Gardens* and *Swimming pools)*, and houses with dishwashers. Since we are only interested in users with individual water meters, we only consider the single-family houses for the garden and swimming pool dummies (water meters in flats do not account for the water consumption in outdoor amenities). To summarize the information about investment in efficient household devices and appliances, we included the variable *Efficient devices*, which is an index representing the presence of efficient water-saving devices such as taps, water tanks, showerheads, and pressure regulators. This variable takes on values of 0, 25, 50, or 100 depending on the proportion of saving devices installed. Additionally, we included the variable *Efficient appliances*, which is an index representing the presence of water- or energy-efficient dishwashing or washing machine appliances. This variable takes on values of 0, 50, or 100 depending on whether the household has none, one, or both appliances.
- **Water-related information:** We constructed the dummy variable *Water habits*, to account for household habits related to water consumption. It takes a value of 1 when the respondent reports having seven or more of the 13 water-saving habits considered.[11] Additionally, we included the dummy variable *Campaign* to account for households that are aware of any campaigns to promote water saving. Regarding household information on water bills, we consider two indicators: a dummy variable taking the value of 1 for those who did not know or did not remember the total cost of their last water bill (*Bill unaware*); and for those who answered, the percentage of underestimation of the total cost of their last water bill (*Bill underestimation*).

Additionally, the dummy variable *Zero* is included to consider the negative variations in water consumption due to temporary or permanent home leaves. As shown in Table 2, average water consumption is higher for women than for men, with consumption levels of 11.716 m^3 and 10.591 m^3, respectively. This difference can likely be attributed to the fact that women's single-gender households have, on average, a higher number of household members, with an average of 1.407 compared to 1.250 household members in men's households.

Regarding household composition, a larger proportion of men are minors and employed in comparison to women. Additionally, women's houses tend to be older, and the proportion of houses with gardens, swimming pools, dishwashers, efficient devices, or efficient appliances is lower. When it comes to water conservation habits, men report slightly more practices and greater awareness about savings campaigns than women. However, a lower percentage of men are uninformed about their water bills (25 % compared to 29.4 % of informed women) and, on average, they underestimate their bill charges by 5.40 %, whereas women's underestimation is only 1.46 %.

3. Results and discussion

3.1. Correction of endogeneity and selection biases

As explained in Section 2.1, the estimation of water demand functions is subject to the problem of endogenous marginal prices due to their simultaneous determination alongside water consumption levels. The Wu-Hausman test of exogeneity in the variable income divided by marginal prices (*Inc/Price*) is rejected, confirming the initial suspicions of the endogeneity of this regressor (see Table B1, Appendix B). The chosen instruments seem to be exogenous, and the model is overidentified, with the number of endogenous

[9] All variables are net of taxes.

[10] More information can be found in https://sede.asturias.es/bopa/2019/12/27/2019-13579.pdf#page=2 \\ https://sede.asturias.es/bopa/2014/07/29/2014-13191.pdf#page=19.

[11] The possible water conservation habits include: water recycling, cooling water by keeping it bottled in the fridge, turning the tap off while soaping hands, not defrosting food with hot water, filling the sink before washing dishes, fully loading the washing machine and dishwasher, reducing water volume by partially closing the shut-off valve, not using the toilet for waste disposal, making use of the partial-flush system on the toilet tank, turning off the tap when brushing teeth, taking showers instead of baths, turning off the shower while soaping up, and not washing the car with residential water.

regressors being lower than the number of instrumental variables, indicating that the problem of endogeneity bias has been properly addressed. Additionally, the estimated marginal effects in Table B1 (Appendix B) align with expectations. For instance, the time lags of the first block prices are negatively correlated with income divided by marginal prices (*Inc/Price*), while households with more employed members or a garden tend to present higher *Inc/Price*. Regarding the owners of a swimming pool, we find a statistically significant negative effect, which is a likely consequence of the high number of zeroes observed for this variable (see Table 2).

Regarding the analysis and correction of the selection bias problem arising from the stratification of the sample into single-gender households (see Section 2.3), the results of the estimated Heckman two-step selection model indicate that the chosen instruments (*National*, *Shared* and *Newcomer*) do not determine water consumption but contribute to explaining the probability of belonging to a single-gender household. Additionally, the estimated inverse of the Mill's ratio significantly explains water consumption in single-gender households, suggesting the presence of selection bias. Moreover, the estimated coefficient of correlation between residuals from the regressions on single-gender consumption and the probability of belonging to a single-gender household is higher than −0.2, further indicating the existence of selection bias in the chosen subsample. The inclusion of the Mill's ratio in the estimation of water demand of women and men households will help alleviate the selection bias problem.

3.2. Estimation results of the Stone-Geary demand function

Table 3 presents the estimates of the Stone-Geary demand function for men, women, and the pooled sample (all households). According to the estimations, we observe that the coefficients remain robust across the subsamples. Water demand increases with income and decreases with marginal prices, as predicted by the theory [6,7,30,70,71]. It's worth noting that in the context of a Stone-Geary demand function, the coefficient for income and price is the same (that observed in *Inc/Price*) but with the opposite sign.

Recall the chosen instruments for endogeneity correction are the first- and second-time lags in water block prices (see Section 2.1). Due to the unbalanced nature of our panel data, where not all observations are available for each household throughout the entire time span, 340 observations are lost for women households, and 213 for men households.

Regarding other socio-economic determinants, we observe that water demand increases with the number of household *Members*, consistent with prior research [27,48,51,52,57,72,73]. Conversely, the percentage of *Minors* (household members under 18 years old) reduces water consumption, similar to findings by Hoyos and Artabe [73]. Additionally, households with a higher proportion of *Seniors* (members over 65 years old) experience increased water demand in the pooled sample, consistent with the results of Schleich and Hillenbrand [72].

Employment status also influences household water consumption patterns. Typically, employed individuals spend less time at home, resulting in lower water consumption levels for households with a higher proportion of employed members, as observed in Binet et al. [27]. Similarly, women and men households with a higher proportion of highly educated individuals tend to consume less water, likely due to greater environmental awareness, as noted in Gilg and Barr [74]. However, this coefficient shows a positive sign for the

Table 3
Estimation results of the Stone-Geary demand function.

Variable	All households		Women		Men	
Inc/Price	0.000^{c}	(5.24)	0.001^{c}	(7.40)	0.002^{c}	(13.47)
Members	5.185^{c}	(41.24)	8.222^{c}	(34.07)	1.942^{c}	(4.37)
Senior	0.019^{c}	(5.57)	0.009	(1.37)	−0.001	(-0.25)
Minor	-0.130^{c}	(-20.27)	-0.090^{c}	(-3.54)	−0.003	(-0.12)
Employed	-0.032^{c}	(-8.67)	-0.034^{c}	(-5.45)	-0.029^{c}	(-5.45)
College	0.022^{c}	(6.19)	-0.032^{c}	(-5.67)	-0.050^{c}	(-9.48)
Old house	2.066^{c}	(9.79)	3.443^{c}	(8.22)	1.885^{c}	(5.40)
Garden	7.028^{c}	(22.66)	2.281^{c}	(3.59)	1.903^{c}	(2.85)
Pool	10.659^{c}	(22.35)	−2.241	(-1.60)	14.896^{c}	(12.95)
Dishwasher	3.489^{c}	(15.34)	3.220^{c}	(8.86)	0.567	(1.62)
Efficient devices	-0.026^{c}	(-6.84)	-0.038^{c}	(-4.76)	0.030^{c}	(4.60)
Efficient appliances	-0.019^{c}	(-7.34)	-0.032^{c}	(-7.01)	−0.003	(-0.69)
Water habits	-2.891^{c}	(-10.06)	-1.370^{c}	(-3.33)	-3.390^{c}	(-6.37)
Campaign	0.090	(0.49)	-0.619^{b}	(-2.14)	-2.365^{c}	(-7.61)
Bill unaware	0.997^{c}	(4.85)	0.069	(0.22)	-0.822^{b}	(-2.40)
Bill underestimation	0.228^{c}	(32.67)	0.118^{c}	(7.41)	0.107^{c}	(13.45)
Zero	-14.501^{c}	(-20.81)	-11.802^{c}	(-13.49)	-8.511^{c}	(-10.63)
Men	0.413	(1.32)	–	–	–	–
Residual	-0.006^{c}	(-46.61)	-0.006^{c}	(-19.13)	-0.005^{c}	(-18.40)
Mills ratio	–	–	-2.420^{b}	(-2.07)	-4.210^{c}	(-3.52)
Constant	2.791^{c}	(3.73)	−1.738	(-0.93)	11.413^{c}	(6.12)
District Effects	YES		YES		YES	
Time Effects	YES		YES		YES	
N^{d}	24,833		4123		2643	
adj. R2	0.387		0.468		0.496	

Notes: "All households" refers to the pooled sample of households, while "Women" refers to the subsample of single-gender women's households, and "Men" to the subsample of single-gender men's households. T statistics in parentheses. ^{a} $p < 0.1$. ^{b} $p < 0.05$. ^{c} $p < 0.01$.

pooled sample. In this sense, mixed-gender households appear to have a significantly different profile compared to single-gender households (mixed-gender households account for more than 72 % of the entire sample).

In terms of housing characteristics, we find that owning older houses (*Old house*) is associated with higher water consumption, possibly due to a higher likelihood of leakages [75,76]. Consistent with previous studies, owning a *Swimming pool* (for men and the pooled sample), and having a *Garden* significantly increases water demand [27,77–79].

Furthermore, owning a *Dishwasher* also contributes to higher levels of water consumption. Although dishwashers are considered efficient appliances [80], their water-saving potential depends on proper usage, such as running them when fully loaded [81]. The proportion of *Efficient devices* installed decreases water consumption in women's households and for the pooled sample, while it increases consumption in men's households. While this may seem counterintuitive, the higher consumption in men's households with a high proportion of efficient devices could be attributed to the rebound effect, as explained by Freire-González [82].

Regarding specific water-saving equipment (*Efficient appliances*), measured by the index of efficient dishwashers and washing machines, we find it to be significant and to exhibit the expected negative sign for all households, consistent with previous studies [78,80,83,84].

As expected, reporting efficient water consumption habits (*Water habits*) reduces water demand. Rajapaksa et al. [85] demonstrated that promoting pro-environmental behaviors results in significant reductions in water consumption. Awareness of a water-saving *Campaign* is linked to reduced water consumption in single-gender households. However, contrary to the results of Hablemitoğlu and Özmete [31], Larson et al. [35] or March et al. [36], it is not a significant determinant of water consumption for the pooled sample.

The variable measuring the degree of underestimation of the last water bill (*Bill underestimation*) is positively and significantly associated at the 1 % level, indicating that the more that households underestimate their water bills, the higher their water consumption. This finding aligns with the results of Binet et al. [27], who observed that individuals tend to increase water consumption when they underestimate marginal prices, as well as with Rajapaksa et al. [85], who identified that monetary incentives encourage reductions in water consumption. Therefore, providing better information to these individuals is likely to increase their consumer surplus, as shown in Wichman [25] and Brent and Ward [26], as increased consumption can be attributed to inefficient demand decisions.

We compute the mean price elasticities and calculate the conditional water use threshold [45] for women and men, as explained in Subsection 2.1. The results are displayed in Table 4. Our analysis reveals that water demand is more price-inelastic for women (−0.59 %) compared to men (−0.94 %). Additionally, the level of conditional water use threshold is higher for women (7.244 m^3/household/billing period or 82 L/capita/day) than for men (4.016 m^3/household/billing period or 57 L/capita/day). These findings suggest that water is a necessity good, with a diminishing relative weight on household expenditure as income increases, and a demand that is relatively insensitive to changes in water prices.

Despite both genders show reluctance to alter their consumption habits in response to price changes, men appear to be relatively more responsive to pricing policies compared to women. For women, the threshold quantities are nearly 62 % of their average water consumption (7.24/11.716 m^3/billing period), indicating limited potential for pricing policy effectiveness in their households. Conversely, for men, this proportion is lower, accounting for approximately 38 % of their consumption (4.01/10.591 m^3/billing period), suggesting they may be more receptive to pricing policies. Consequently, women may be the primary target group for alternative non-pricing strategies.

To determine the extent to which differences in the conditional water use threshold are influenced by idiosyncratic variables such as household members or average age, or variables related to environmental awareness and information biases, which can be addressed through the implementation of nudges and other non-pricing policies, we employ the Oaxaca-Blinder decomposition.

In addition, the results of the pooled regression in Table 3 indicate that, after incorporating all control variables considered in the analysis, men's households demand, on average, more water than women (the dummy regressor *Men* is positive and significantly different from zero). The Oaxaca-Blinder decomposition will further enable us to assess the extent to which this disparity is attributable to unobserved differences in characteristics between men and women influencing residential water demand, or to differences in the responsiveness of each gender to the control variables.

3.3. Oaxaca–blinder decomposition for gender differences in water demand

According to Table 5, differences in the total average water consumption between genders are statistically significant at the 1 % level, indicating that women households (our reference group) consume more water than those formed by men (with overall average consumption for women at 11.760 m^3 and for men at 10.643 m^3). Specifically, women's households consume, on average, an additional 1.117 m^3 compared to men's households.

As shown in Table 5, the explained part of the Oaxaca-Blinder decomposition is statistically significant at the 1 % level, accounting for over 92 % of the total gap of 1.117 m^3. This means that women households consume 1.033 m^3 more than men households mainly

Table 4
Estimated conditional water use threshold and price elasticity.

	Women	Men	Diff *t*-test
Threshold	7.244	4.016	3.227[c]
Price elasticity	−0.591	−0.944	−0.352[c]

[a] $p < 0.1$. [b] $p < 0.05$. [c] $p < 0.01$.

due to weighted differences in the observable characteristics included in our analysis.

The unexplained part is further divided into differences between the pooled regression and the regressions for women and men. Table 5 presents the unexplained part of the differences in water consumption, amounting to 0.083 m^3, which accounts for less than 8 % and is not jointly statistically different from zero. We will analyze the components of each part of the decomposition in the following subsections.

3.3.1. *Explained part of gender water consumption differences*

Analyzing the determinants of the explained part of water consumption differences (as shown in the "Explained" column of Table 5), we observed that many explanatory variables of the Stone-Geary demand function are significantly different from zero. The reference coefficients are those of the pooled regression (the "All households" column of Table 3) and women are the reference group for the Oaxaca-Blinder decomposition (refer to equation (6) in Subsection 2.2).

In terms of household socioeconomic characteristics, we find that women's household characteristics contribute to higher water consumption among women. If we isolate these characteristics, the consumption gap would be 1.515 m^3 instead of the actual 1.117 m^3. The most significant factor explaining this gap is the number of household *Members*, with women consuming 0.815 m^3 more than men. This calculation is computed as the difference between the average number of members in women's households and in men's households (1.407 and 1.250 members respectively, as shown in Table 2) multiplied by the coefficient of *Members* estimated for the pooled sample ("All households" column, 5.185, as shown in Table 3).

Other significant characteristics explaining the higher consumption in women's households are the percentage of *Employed* (0.336 m^3), *Seniors* (0.262 m^3) and *Minors* (0.124 m^3). Therefore, the higher average water consumption in women's households can be mainly explained by their larger household sizes, formed by more aged and unemployed members. It is worth noting that the number of total and senior members increases water consumption, while the number of minor and employed members decreases water consumption (as seen in Section 3.2).

We also find that, on average, women consume 0.294 m^3 more than men due to their housing characteristics. On the one hand, women in our sample tend to be endowed with older houses, which leads to an explained increase in water consumption differences by 0.279 m^3 (all else being equal). On the other hand, women in our sample are less likely to own a garden or a dishwasher, which, according to Table 3, increase water consumption. For these reasons, women tend to consume 0.254 m^3 and 0.126 m^3 less compared to men.

Finally, if we isolate the effect of gender differences in water information, we observe that women consume 0.743 m^3 less compared to men. This suggests that women tend to be better informed than men (according to Table 3, better information implies lower consumption levels). This is mainly explained by the degree of underestimation of the total water invoice (*Bill underestimation*).

Table 5
Oaxaca-Blinder decomposition of water consumption by gender.

Women consumption	11.760^c		(67.94)	
Men consumption	10.643^c		(58.52)	
Difference	1.117c		(4.45)	
Explained	1.033c		(4.65)	
Unexplained	0.083		(0.37)	
	Explained		**Unexplained**	
Household socioeconomic	1.515c	(14.09)	6.247c	(4.54)
Inc/Price	−0.024	(-1.10)	−1.985	(-1.13)
Members	0.815c	(10.57)	8.200^c	(8.36)
Senior	0.262c	(3.99)	0.240	(0.90)
Minor	0.124^c	(3.25)	−0.130b	(-2.01)
Employed	0.336c	(5.70)	−0.374	(-0.92)
College	0.003	(0.15)	0.295	(1.21)
Housing characteristics	0.294c	(2.96)	−2.953c	(-5.40)
Old house	0.279c	(6.71)	0.214c	(2.73)
Garden	−0.254c	(-4.60)	0.053	(0.11)
Pool	0.059	(1.50)	−0.402c	(-4.41)
Dishwasher	−0.126c	(-2.88)	−0.122c	(-2.60)
Efficient devices	0.193c	(5.52)	−1.337c	(-9.23)
Efficient appliances	0.142c	(4.68)	−1.455c	(-4.13)
Water-related information	−0.743c	(-6.66)	1.064c	(3.77)
Water habits	0.128c	(4.84)	0.786c	(3.35)
Campaign	−0.012	(-0.54)	0.040	(0.75)
Bill unaware	0.045c	(3.05)	−0.232b	(-2.39)
Bill underestimation	−0.903c	(-8.60)	0.519c	(3.74)
Other	−0.033	(-0.25)	−4.275c	(-3.02)
Total	1.033c	(4.65)	0.083	(0.37)

Notes: t statistics in parentheses. $^a p < 0.1$. $^b p < 0.05$. $^c p < 0.01$.

According to our data, men underestimated their last water bill by more than 5.4 %, on average, while women did it only by around 1.5 % (see Table 2 in Subsection 2.3). Even though women can still improve their environmental awareness and water-saving habits, their overall information seems to be significantly better than that of men, which may be a consequence of their higher aversion to risk [23].

3.3.2. Unexplained part of gender water consumption differences

Exploring the differences between the coefficients of the pooled sample regression and the regressions for women and men (see the "Unexplained" column in Table 5), these are not statistically significant or different from zero altogether. This is mainly due to the differences in the estimated intercept term (-4.275 m^3), canceling out the estimated coefficient differences in Table 5 (the sum of the unexplained household socioeconomic, housing characteristics, and water-related information equals 4.376 m^3). Besides, it can be observed that differences in the marginal effects associated with socioeconomic characteristics seem to increase water consumption across women's households by 6.247 m^3, mainly because of the high sensitivity of women's households to changes in their number of members compared to the representative household (see Table 3). Regarding the marginal effects of housing characteristics, women's households seem to be less sensitive to changes in their endowments, leading to an overall reduction of water consumption of 2.953 m^3 compared to men's households. Finally, women's households appear to be more sensitive to changes in their water bill information, resulting in an increase in their overall consumption by 1.064 m^3.

4. Conclusions

The determinants of household water consumption have been extensively studied by numerous authors in the literature. Consequently, the impact of various household characteristics on water demand has been well-documented, including factors such as income, number of household members, and the presence of a garden or swimming pool (see, for example, Makki et al. [86]; Arbués et al. [87]; Garcia-Valiñas et al. [88]; Renzetti et al. [89]; or Hoyos and Artabe [73]). However, the impact of gender on household water consumption has not been adequately identified thus far, as previous studies have primarily focused on mixed-gender families. To the best of our knowledge, research papers that incorporate gender into their analysis of residential water demand have relied on proxies for household gender, such as the proportion of women and men in the region, the percentage of women household members, or the gender of the head of the household [30,37,39].

Information about the primary water consumers within a household is crucial for targeting specific individuals when designing effective public policies and sustainable water resource management. Further analysis of water consumption by gender can contribute to informed decision-making. Unfortunately, this aspect is often overlooked due to challenges in data collection, as water usage is typically measured by at the household level rather than at the individual level. In this paper, we had the unique advantage of accurately identifying gender differences in residential water consumption by considering single-gender households. We gathered data on household characteristics via a survey and tracked bimonthly water consumption for 275 single-gender households in the city of Gijón, located in the region of Asturias, Spain. Our dataset spans 28 billing periods, covering the period from 2017 to 2021.

First, we estimated a Stone-Geary demand function for water consumption separately for each gender. We then calculated price-income elasticities and determined the level of conditional water use threshold. Our findings indicate that water demand is more elastic among men, whereas the level of conditional water use threshold is higher among women. Based on these results, we infer that women's households exhibit stronger habits and are likely to be less responsive to any pricing or tariff policies aimed at promoting water conservation and reducing household consumption.

Secondly, we employed the Oaxaca-Blinder decomposition to analyze the disparities in water usage between women and men. Our findings indicate that women's households tend to consume more water compared to men's households, which is in line with previous studies by Horsburgh et al. [33] and Reynaud [30]. These differences can be primarily attributed to the observable household characteristics considered in our analysis. The key factors that explain higher consumption in women's households include having a higher number of household members, a higher proportion of elderly and unemployed individuals, older houses, fewer water-saving appliances, and reporting poorer water-saving habits compared to men's households. Other differences between genders, not explainable through distinct household characteristics but by different coefficients, may be due to different preferences or some cultural or behavioral patterns, but according to our findings, these differences are minor.

Our findings could have significant public policy implications. However, these must be considered with caution, given that our sample lacks representativity of the overall population. Our results show that nudging Thaler [90] or boosting Grüne-Yanoff [91] strategies might be more effective if tailored to the gender of the recipient. On the one hand, the Oaxaca-Blinder decomposition reveals that men in our sample tend to have poorer information about their water bills. On the other hand, women in our sample may need to enhance their water-saving habits and use more efficient household equipment to consume less water. Utilizing social comparison tools, setting conservation goals, and providing financial information, can help both men and women become more aware of key dimensions regarding water consumption and behave more efficiently in certain situations [26,92]. Furthermore, water bills could be redesigned to enhance transparency, facilitating comprehension of all water tariff components. Academic and institutional forums strongly recommend simplifying water tariffs, which is expected to reduce underestimation of both the monetary and moral costs of water services [93].

Beyond the specific design of water tariffs and bills, educational and awareness programs targeting specific groups, such as single-gender households with higher consumption levels, could be beneficial. These groups can be identified based on their declared characteristics, as shown in our study. Additionally, incentives such as rebates on water-efficient appliances, to address leaks or improve building thermal insulation could be implemented. These initiatives would target households that stand to benefit the most from adopting new technologies and practices to reduce water consumption.

In addition to household-focused policies, specific tools at the individual level can be developed. For instance, residents of the sampled city of Gijón have access to a mobile app called "App Gijón", which allows them to pay public transport fees, check the city's air quality, or pay water bills, among other services. This free app requires users to register their data, including gender, age, or area of residence. Through this app, it would be possible to implement individual-level water-saving strategies based on the user's gender, benefiting from tailored measures in line with the results of our work. Policymakers could improve water billing information, such as prices, tariffs, or the real cost of water, differently for women and men. Similar local government apps can also be found in other cities in Spain, Canada or Germany.

The findings of this study should be interpreted in light of a significant limitation, namely, the restriction to households where all members are either men or women. This sample characteristic may introduce a potential source of bias, as it does not capture the diversity present within the broader population. Consequently, caution should be exercised when generalizing the results to the overall population, as the study's design does not permit the examination of households with mixed-gender compositions. Another limitation is that, since most differences in water consumption across single-gender households are explained by differences in household socioeconomic characteristics, the potential impact of policies is likely to be limited.

Statements and declarations

The authors would like to thank the European Commission and the Spanish Ministry of Science, Innovation and Universities for funding in the frame of the collaborative international consortium NEWTS financed under the 2018 Joint call of the WaterWorks 2017 ER A-NET Cofund (MCIU-19-PCI2019-103676). This ERA-NET is an integral part of the activities developed by the Water JPI.

CRediT authorship contribution statement

Roberto Balado-Naves: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sara Suárez-Fernández:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgments

The authors would like to thank the European Commission and the Spanish Ministry of Science, Innovation and Universities for funding in the frame of the collaborative international consortium NEWTS financed under the 2018 Joint call of the WaterWorks 2017 ERA-NET Cofund (MCIU-19-PCI2019-103676). This ERA-NET is an integral part of the activities developed by the Water JPI.

APPENDIX A

Table A1
Main statistics (pooled sample, single- and mixed-gender samples).

Variable	All households (N = 26,860)		Single gender (N = 7319)		Mixed gender (N = 19,541)	
	Mean	SD	Mean	SD	Mean	SD
Consumption	17.277	17.323	11.277	10.428	19.525	18.795
Income	4153.341	1454.294	3141.19	1219.7	4532.438	1350.025
Price	1.036	0.17	1.016	0.139	1.043	0.18
Inc/Price	4209.737	2145.271	3315.24	2170.297	4544.767	2037.161
Men	0.106	0.308	0.39	0.488	–	–
Members	2.441	1.069	1.346	0.621	2.852	0.9
Seniors	28.825	41.162	40.725	46.666	24.368	37.953
Minors	10.585	18.357	2.546	10.992	13.596	19.613
Employed	43.301	37.174	42.267	45.829	43.689	33.352
College	17.975	29.963	18.577	36.309	17.749	27.205

(*continued on next page*)

Table A1 (*continued*)

Variable	All households (N = 26,860)		Single gender (N = 7319)		Mixed gender (N = 19,541)	
	Mean	SD	Mean	SD	Mean	SD
Old house	0.484	0.5	0.617	0.486	0.434	0.496
Garden	0.199	0.399	0.096	0.294	0.239	0.426
Pool	0.044	0.204	0.023	0.149	0.051	0.221
Dishwasher	0.617	0.486	0.431	0.495	0.687	0.464
Efficient devices	21.123	24.897	16.01	21.347	23.039	25.845
Efficient appliances	55.549	42.087	46.673	39.808	58.874	42.435
Water habits	0.89	0.313	0.895	0.307	0.888	0.315
Campaign	0.404	0.491	0.391	0.488	0.409	0.492
Bill unaware	0.255	0.436	0.277	0.448	0.247	0.431
Bill underestimation	3.006	12.767	3.003	13.622	3.007	12.431
Zero	0.017	0.129	0.025	0.157	0.014	0.117
National	0.976	0.115	0.979	0.13	0.975	0.108
Shared	0.01	0.101	0.023	0.15	0.006	0.075
Newcomer	0.129	0.335	0.148	0.355	0.122	0.327
House surface	106.527	75.471	87.127	48.083	113.793	82.278

APPENDIX B

Table B1
Estimation results of the control function for *Inc/Price* (All households).

Variable		
Block 1 Price (t-1)	−21253.107***	(-27.15)
Block 1 Price (t-2)	−10288.951***	(-13.15)
Members	689.068***	(100.07)
Seniors	−0.032	(-0.16)
Minors	5.947***	(15.71)
Employed	11.899***	(57.43)
College	19.753***	(104.64)
Old house	−93.475***	(-7.51)
Garden	340.127***	(19.15)
Pool	−160.115***	(-5.68)
Dishwasher	22.114*	(1.65)
Efficient devices	1.343***	(6.05)
Efficient appliances	1.105***	(7.43)
Water habits	−7.206	(-0.43)
Campaign	−60.345***	(-5.58)
Bill unaware	−106.003***	(-8.74)
Bill underestimation	−4.918***	(-11.97)
Zero	−61.296	(-1.49)
Men	29.237	(1.58)
Constant	19346.147***	(226.35)
District Effects	X	
Time Effects	X	
N	24,833	
adj. R2	0.856	
H_0: *Inc/Price* is exogenous		
Wu-Hausman F (1, 24,790)	2172.46***	(p = 0.000)
H_0: instruments are weak		
F (2, 24,790)	27997.2***	(p = 0.000)
H_0: instruments are valid (overidentifying restrictions)		
Sargan-Hansen χ^2(1)	0.581	(p = 0.446)

Notes: t statistics in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01.

APPENDIX C

Table C1
Estimation results of the Heckman selection model.

Variable	Single-gender household consumption	
Inc/Price	0.001***	(10.76)
Members	7.674***	(39.28)
Seniors	0.011**	(2.40)
Minors	−0.130***	(-6.84)
Employed	−0.027***	(-6.47)
College	−0.031***	(-8.01)
Old house	2.240***	(8.12)
Garden	3.895***	(8.73)
Pool	1.981**	(2.32)
Dishwasher	2.124***	(8.29)
Efficient devices	0.009*	(1.85)
Efficient appliances	−0.024***	(-7.42)
Water habits	−1.761***	(-5.43)
Campaign	−0.966***	(-4.55)
Bill unaware	−0.346	(-1.51)
Bill underestimation	0.108***	(14.30)
Zero	−10.829***	(-17.24)
Men	0.630***	(2.94)
Residual	−0.006***	(-25.64)
Constant	0.489	(0.35)
District Effects	YES	
Time Effects	YES	
N	6766	
Test joint significance instruments F (3,6720)	2.01	(p = 0.111)
	Probit model for single-gender households	
Seniors	0.005***	(16.82)
Minors	−0.022***	(-32.85)
Employed	0.003***	(9.89)
College	−0.000	(-0.40)
National	0.008	(0.12)
Shared	0.979***	(11.88)
Newcomer	0.309***	(11.57)
Constant	−0.848***	(-11.32)
Mill's ratio	−1.946**	(-2.25)
rho	−0.241	
sigma	8.051	
N	26,307	

t statistics in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01.

APPENDIX D

Table D1
Estimation results of the interval regression for *Income*.

Variable		
Members	392.227***	(67.30)
Employed	5.801***	(33.65)
College	8.985***	(41.29)
House surface	3.864***	(37.15)
Constant	394.879***	(16.12)
District Effects	X	
N	24,108	
LR test district effects χ^2(10)	368.17***	(p = 0.000)

t statistics in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01. The municipality has been divided into 11 districts following the water supply areas established by the EMA.

APPENDIX E

Table E1
Water block price scheme in Gijón (2017–2021).

Overall consumption	Block 1 (≤ 30 m^3)	Block 2 (30–50 m^3)	Block 3 (>50 m^3)
Before January 2020			
≤30 m^3	1.02234 €/m^3		
30–50 m^3	1.10224 €/m^3	1.29892 €/m^3	
>50 m^3	1.18204 €/m^3	1.37872 €/m^3	1.549 €/m^3
From January 2020 onwards			
≤30 m^3	1.05347 €/m^3		
30–50 m^3	1.13337 €/m^3	1.33984 €/m^3	
>50 m^3	1.21317 €/m^3	1.41964 €/m^3	1.5985 €/m^3

Elaborated by the authors using data from BOPA núm. 300 de 30-xii-2014, núm. 248 de 27-xii-2019, núm. 175 de 29-VII-2014.

References

[1] M.M. Mekonnen, A.Y. Hoekstra, Four billion people facing severe water scarcity, Sci. Adv. 2 (2) (2016) e1500323.
[2] WMO, 2021 State of Climate Services, World Meteorological Organization (WMO), 2021. No. 1278.
[3] F. Dolan, J. Lamontagne, R. Link, M. Hejazi, P. Reed, J. Edmonds, Evaluating the economic impact of water scarcity in a changing world, Nat. Commun. 12 (1) (2021) 1915.
[4] C. He, Z. Liu, J. Wu, X. Pan, Z. Fang, J. Li, B.A. Bryan, Future global urban water scarcity and potential solutions, Nat. Commun. 12 (1) (2021) 4667.
[5] United Nations, About the Sustainable Development Goals. https://www.un.org/sustainabledevelopment/sustainable-development-goals/.
[6] M.Á. García-Valiñas, S. Suárez-Fernández, Are economic tools useful to manage residential water demand? A review of old issues and emerging topics, Water 14 (16) (2022) 2536.
[7] F. Arbués, M.Á. Garcıa-Valiñas, R. Martınez-Espiñeira, Estimation of residential water demand: a state-of-the-art review, J. Soc. Econ. 32 (1) (2003) 81–102.
[8] P.J. Ferraro, J.J. Miranda, M.K. Price, The persistence of treatment effects with norm-based policy instruments: evidence from a randomized environmental policy experiment, Am. Econ. Rev. 101 (3) (2011) 318–322.
[9] P.J. Ferraro, J.J. Miranda, Heterogeneous treatment effects and mechanisms in information-based environmental policies: evidence from a large-scale field experiment, Resour. Energy Econ. 35 (3) (2013) 356–379.
[10] P.J. Ferraro, M.K. Price, Using nonpecuniary strategies to influence behavior: evidence from a large-scale field experiment, Rev. Econ. Stat. 95 (1) (2013) 64–73.
[11] P.W. Schultz, A. Messina, G. Tronu, E.F. Limas, R. Gupta, M. Estrada, Personalized normative feedback and the moderating role of personal norms: a field experiment to reduce residential water consumption, Environ. Behav. 48 (5) (2016) 686–710.
[12] M. Bernedo, P.J. Ferraro, M. Price, The persistent impacts of norm-based messaging and their implications for water conservation, J. Consum. Pol. 37 (2014) 437–452.
[13] T. Dietz, L. Kalof, P.C. Stern, Gender, values, and environmentalism, Soc. Sci. Q. 83 (1) (2002) 353–364.
[14] A. Biel, A. Nilsson, Religious values and environmental concern: harmony and detachment, Soc. Sci. Q. 86 (1) (2005) 178–191.
[15] K. Davies, C. Doolan, R. Van Den Honert, R. Shi, Water-saving impacts of Smart Meter technology: an empirical 5 year, whole-of-community study in Sydney, Australia, Water Resour. Res. 50 (9) (2014) 7348–7358.
[16] L.C. Zelezny, P.-P. Chua, C. Aldrich, New ways of thinking about environmentalism: elaborating on gender differences in environmentalism, J. Soc. Issues 56 (2000) 443–457.
[17] I.B. Addo, M.C. Thoms, M. Parsons, Household water use and conservation behavior: a meta-analysis, Water Resour. Res. 54 (2018) 8381–8400.
[18] C. Olivetti, B. Petrongolo, Unequal pay or unequal employment? A cross-country analysis of gender gaps, J. Labor Econ. 26 (4) (2008) 621–654.
[19] C. Olivetti, B. Petrongolo, The evolution of gender gaps in industrialized countries, Annual review of Economics 8 (2016) 405–434.
[20] F.D. Blau, L.M. Kahn, The gender wage gap: extent, trends, and explanations, J. Econ. Lit. 55 (3) (2017) 789–865.
[21] E. Duflo, Women empowerment and economic development, J. Econ. Lit. 50 (4) (2012) 1051–1079.
[22] S. Klasen, Gender, institutions, and economic development, in: Grow Working Paper Series, Institute for the Study of International Development, McGill University, Montreal, 2017.
[23] R. Croson, U. Gneezy, Gender differences in preferences, J. Econ. Lit. 47 (2) (2009) 448–474.
[24] C.J. Wichman, Perceived price in residential water demand: evidence from a natural experiment, J. Econ. Behav. Organ. 107 (2014) 308–323.
[25] C.J. Wichman, Information provision and consumer behavior: a natural experiment in billing frequency, J. Publ. Econ. 152 (2017) 13–33.
[26] D.A. Brent, M.B. Ward, Price perceptions in water demand, J. Environ. Econ. Manag. 98 (2019) 102266.
[27] M.E. Binet, F. Carlevaro, M. Paul, Estimation of residential water demand with imperfect price perception, Environ. Resour. Econ. 59 (2014) 561–581.
[28] M.Á. García-Valiñas, R. Martínez-Espiñeira, M. Suárez-Varela Maciá, Price and consumption misperception profiles: the role of information in the residential water sector, Environ. Resour. Econ. 80 (2021) 821–857.
[29] X. Mu, D. Whittington, J. Briscoe, Modeling village water demand behavior: a discrete choice approach, Water Resour. Res. 26 (4) (1990) 521–529.
[30] A. Reynaud, Modelling household water demand in Europe–insights from a cross-country econometric analysis of EU-28 countries, Insights from a Cross-Country Econ. Analy. EU 28 (2015).
[31] S. Hablemitoğlu, E. Özmete, Sustainable water management: a case study on saving behaviour of Turkish women for domestic water usage, Eur. J. Soc. Sci. 12 (3) (2010) 447–456.
[32] Y. Tong, L. Fan, H. Niu, Water conservation awareness and practices in households receiving improved water supply: a gender-based analysis, J. Clean. Prod. 141 (2017) 947–955.
[33] J.S. Horsburgh, M.E. Leonardo, A.M. Abdallah, D.E. Rosenberg, Measuring water use, conservation, and differences by gender using an inexpensive, high frequency metering system, Environ. Model. Software 96 (2017) 83–94.
[34] D. Karlis, V.G. Vasdekis, M. Banti, Heteroscedastic semiparametric models for domestic water consumption aggregated data, Environ. Ecol. Stat. 16 (2009) 355–367.
[35] K.L. Larson, D.C. Ibes, D.D. White, Gendered perspectives about water risks and policy strategies: a tripartite conceptual approach, Environ. Behav. 43 (3) (2011) 415–438.

[36] H. March, L. Domènech, D. Saurí, Water conservation campaigns and citizen perceptions: the drought of 2007–2008 in the Metropolitan Area of Barcelona, Nat. Hazards 65 (2013) 1951–1966.
[37] S. Kayaga, J. Calvert, K. Sansom, Paying for water services: effects of household characteristics, Util. Pol. 11 (3) (2003) 123–132.
[38] J. Garcia, L.R. Salfer, A. Kalbusch, E. Henning, Identifying the drivers of water consumption in single-family households in Joinville, Southern Brazil, Water 11 (10) (2019) 1990.
[39] A. Grespan, J. Garcia, M.P. Brikalski, E. Henning, A. Kalbusch, Assessment of water consumption in households using statistical analysis and regression trees, Sustain. Cities Soc. 87 (2022) 104186.
[40] R. Räty, A. Carlsson-Kanyama, Energy consumption by gender in some European countries, Energy Pol. 38 (1) (2010) 646–649, 2010.
[41] R. Oaxaca, Male-female wage differentials in urban labor markets, Int. Econ. Rev. (1973) 693–709.
[42] A.S. Blinder, Wage discrimination: reduced form and structural estimates, J. Hum. Resour. (1973) 436–455.
[43] B. Lin, M.A. Okyere, Race and energy poverty: the moderating role of subsidies in South Africa, Energy Econ. 117 (2023) 106464.
[44] M. Liu, C. Fang, Y. Bai, B. Sun, X. Liao, Z. Liu, Regional inequality and urban-rural difference of dietary water footprint in China, Resour. Conserv. Recycl. 199 (2023) 107236.
[45] S. Gaudin, R.C. Griffin, R.C. Sickles, Demand specification for municipal water management: evaluation of the Stone-Geary form, Land Econ. 77 (3) (2001) 399–422.
[46] R. Martínez-Espiñeira, C. Nauges, Is all domestic water consumption sensitive to price control? Appl. Econ. 36 (15) (2004) 1697–1703.
[47] Y.N. Madhoo, Policy and nonpolicy determinants of progressivity of block residential water rates–a case study of Mauritius, Appl. Econ. Lett. 16 (2) (2009) 211–215.
[48] M.A. García-Valiñas, R. Martínez-Espiñeira, F. González-Gómez, Affordability of residential water tariffs: alternative measurement and explanatory factors in southern Spain, J. Environ. Manag. 91 (12) (2010) 2696–2706.
[49] D. Dharmaratna, E. Harris, Estimating residential water demand using the Stone-Geary functional form: the case of Sri Lanka, Water Resour. Manag. 26 (2012) 2283–2299.
[50] A.J. Clarke, B.G. Colby, G.D. Thompson, Household water demand seasonal elasticities: a stone-geary model under an increasing block rate structure, Land Econ. 93 (4) (2017) 608–630.
[51] M.F. Hung, B.T. Chie, T.H. Huang, Residential water demand and water waste in Taiwan, Environ. Econ. Pol. Stud. 19 (2017) 249–268.
[52] D. Roibás, M.A. Garcia-Valiñas, R. Fernandez-Llera, Measuring the impact of water supply interruptions on household welfare, Environ. Resour. Econ. 73 (2019) 159–179.
[53] J.A. Nordin, A proposed modification of Taylor's demand analysis: comment, Bell J. Econ. (1976) 719–721.
[54] S.M. Olmstead, W.M. Hanemann, R.N. Stavins, Water demand under alternative price structures, J. Environ. Econ. Manag. 54 (2) (2007) 181–198.
[55] S.M. Olmstead, Reduced-form versus structural models of water demand under nonlinear prices, J. Bus. Econ. Stat. 27 (1) (2009) 84–94.
[56] A. Szabo, The value of free water: analyzing South Africa's free basic water policy, Econometrica 83 (5) (2015) 1913–1961.
[57] M. Pérez-Urdiales, M.A. García-Valiñas, R. Martínez-Espiñeira, Responses to changes in domestic water tariff structures: a latent class analysis on household-level data from Granada, Spain, Environ. Resour. Econ. 63 (2016) 167–191.
[58] J.M. Wooldridge, Control function methods in applied econometrics, J. Hum. Resour. 50 (2) (2015) 420–445.
[59] D. Neumark, Employers' discriminatory behavior and the estimation of wage discrimination, J. Hum. Resour. 23 (3) (1988) 279–295.
[60] R.L. Oaxaca, M.R. Ransom, On discrimination and the decomposition of wage differentials, J. Econom. 61 (1) (1994) 5–21.
[61] B. Jann, A Stata implementation of the Blinder-Oaxaca decomposition, STATA J. 8 (4) (2008) 453–479.
[62] J. Gardeazabal, A. Ugidos, More on identification in detailed wage decompositions, Rev. Econ. Stat. 86 (4) (2004) 1034–1036.
[63] Gobierno del Principado de Asturias, Plan Director de Abastecimiento de Aguas del Principado de Asturias 2020-2030, Consejo de Gobierno del Principado de Asturias, 2022. Available at: https://transparencia.asturias.es/detalle/-/categories/694060?p_r_p_categoryId=694060&_com_liferay_asset_categories_navigation_web_portlet_AssetCategoriesNavigationPortlet_articleId=1414203&articleId=1414203&title=Plan%20Director%20de%20Abastecimiento%20de%20Aguas%20del%20Principado%20de%20Asturias%202020-2030&redirect=. %3A%2F%2Ftransparencia.asturias.es%2Fast%2Fgeneral%2F-%2Fcategories%2F694060%3Fp_r_p_categoryId%3D694060.
[64] Centro de Estudios Hidrográficos del CEDEX, Evaluación del impacto del cambio climático en los recursos hídricos y sequías en España, Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, 2017.
[65] R. Gronau, Wage comparisons–A selectivity bias, J. Polit. Econ. 82 (6) (1974) 1119–1143.
[66] H.G. Lewis, Comments on selectivity biases in wage comparisons, J. Polit. Econ. 82 (6) (1974) 1145–1155.
[67] J.J. Heckman, The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models, Ann. Econ. Soc. Meas. 5 (number 4) (1976) 475–492.
[68] J.J. Heckman, Sample selection bias as a specification error, Econometrica: J. Econom. Soc. (1979) 153–161.
[69] F. Carlevaro, C. Schlesser, M.E. Binet, S. Durand, M. Paul, Econometric modeling and analysis of residential water demand based on unbalanced panel data, Прикладная эконоМетрика (4) (2007) 81–100.
[70] A.C. Worthington, M. Hoffman, An empirical survey of residential water demand modelling, J. Econ. Surv. 22 (5) (2008) 842–871.
[71] C. Nauges, D. Whittington, Estimation of water demand in developing countries: an overview, World Bank Res. Obs. 25 (2) (2010) 263–294.
[72] J. Schleich, T. Hillenbrand, Determinants of residential water demand in Germany, Ecol. Econ. 68 (6) (2009) 1756–1769.
[73] D. Hoyos, A. Artabe, Regional differences in the price elasticity of residential water demand in Spain, Water Resour. Manag. 31 (2017) 847–865.
[74] A. Gilg, S. Barr, Behavioural attitudes towards water saving? Evidence from a study of environmental actions, Ecol. Econ. 57 (3) (2006) 400–414.
[75] C. Nauges, A. Thomas, Privately operated water utilities, municipal price negotiation, and estimation of residential water demand: the case of France, Land Econ. (2000) 68–85.
[76] S. Garcia, A. Reynaud, Estimating the benefits of efficient water pricing in France, Resour. Energy Econ. 26 (1) (2004) 1–25.
[77] D.E. Agthe, R.B. Billings, Equity, price elasticity, and household income under increasing block rates for water, Am. J. Econ. Sociol. 46 (3) (1987) 273–286.
[78] M.D.L.Á. García-Valiñas, F. González-Gómez, A.J. Picazo-Tadeo, Is the price of water for residential use related to provider ownership? Empirical evidence from Spain, Util. Pol. 24 (C) (2013) 59–69.
[79] L. Jayarathna, D. Rajapaksa, S. Managi, W. Athukorala, B. Torgler, M.A. Garcia-Valiñas, C. Wilson, A GIS based spatial decision support system for analysing residential water demand: a case study in Australia, Sustain. Cities Soc. 32 (2017) 67–77.
[80] M. Pérez-Urdiales, M.Á. García-Valiñas, Efficient water-using technologies and habits: a disaggregated analysis in the water sector, Ecol. Econ. 128 (2016) 117–129.
[81] R. Martínez-Espiñeira, M.A. García-Valiñas, C. Nauges, Households' pro-environmental habits and investments in water and energy consumption: determinants and relationships, J. Environ. Manag. 133 (2014) 174–183.
[82] J. Freire-González, Does water efficiency reduce water consumption? The economy-wide water rebound effect, Water Resour. Manag. 33 (6) (2019) 2191–2202.
[83] M.E. Renwick, R.D. Green, Do residential water demand side management policies measure up? An analysis of eight California water agencies, J. Environ. Econ. Manag. 40 (1) (2000) 37–55.
[84] K. Rathnayaka, H. Malano, M. Arora, B. George, S. Maheepala, B. Nawarathna, Prediction of urban residential end-use water demands by integrating known and unknown water demand drivers at multiple scales II: model application and validation, Resour. Conserv. Recycl. 118 (2017) 1–12.
[85] D. Rajapaksa, R. Gifford, B. Torgler, M. Garcia-Valiñas, W. Athukorala, S. Managi, C. Wilson, Do monetary and non-monetary incentives influence environmental attitudes and behavior? Evidence from an experimental analysis, Resour. Conserv. Recycl. 149 (2019) 168–176.
[86] A.A. Makki, R.A. Stewart, C.D. Beal, K. Panuwatwanich, Novel bottom-up urban water demand forecasting model: revealing the determinants, drivers and predictors of residential indoor end-use consumption, Resour. Conserv. Recycl. 95 (2015) 15–37.
[87] F. Arbués, I. Villanua, R. Barberán, Household size and residential water demand: an empirical approach, Aust. J. Agric. Resour. Econ. 54 (1) (2010) 61–80.

[88] M.A. Garcia-Valiñas, W. Athukorala, C. Wilson, B. Torgler, R. Gifford, Nondiscretionary residential water use: the impact of habits and water-efficient technologies, Aust. J. Agric. Resour. Econ. 58 (2) (2014) 185–204.
[89] S. Renzetti, D.P. Dupont, T. Chitsinde, An empirical examination of the distributional impacts of water pricing reforms, Util. Pol. 34 (2015) 63–69.
[90] R.H. Thaler, From cashews to nudges: the evolution of behavioral economics, Am. Econ. Rev. 108 (6) (2018) 1265–1287.
[91] T. Grüne-Yanoff, Boosts vs. nudges from a welfarist perspective, Rev. Écon. Polit. (2) (2018) 209–224.
[92] D.A. Brent, C. Lott, M. Taylor, J. Cook, K. Rollins, S. Stoddard, What causes heterogeneous responses to social comparison messages for water conservation? Environ. Resour. Econ. 77 (2020) 503–537.
[93] F. Arbués, M. García-Valiñas, Water Tariffs in Spain, Oxford Research Encyclopedias, 2020.
[94] A. Grønhøj, F. Ölander, A gender perspective on environmentally related family consumption, J. Consum. Behav.: Int. Res. Rev. 6 (4) (2007) 218–235.
[95] C.F. Manski, E. Tamer, Inference on regressions with interval data on a regressor or outcome, Econometrica 70 (2) (2002) 519–546.
[96] E. Van Doorslaer, A.M. Jones, Inequalities in self-reported health: validation of a new approach to measurement, J. Health Econ. 22 (1) (2003) 61–87.