ECONOMIC DISCUSSION PAPERS

Efficiency Series Paper 06/2023

Residential water demand: Gender differences in water consumption

Roberto Balado-Naves, Sara Suarez-Fernandez

Departamento de Economía

Universidad de Oviedo

Available online at: https://www.unioviedo.es/oeg/

Residential water demand:

Gender differences in water consumption

Roberto Balado-Naves[1] and Sara Suarez-Fernandez[2]

September 12, 2023

[1] baladoroberto@uniovi.es University of Oviedo, Department of Economics
[2] suarezfsara@uniovi.es University of Oviedo, Department of Economics
Faculty of Economics and Business, Avd. El Cristo s/n
University of Oviedo, Oviedo, Spain

Abstract

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 Gij'on, Spain. Our approach involves two main steps: firstly, estimating a Stone-Geary demand function for water consumption in both women and men households, and secondly, employing the Oaxaca-Blinder decomposition to examine gender differences. 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. Moreover, our analysis indicates that there is no unexplained gap in water consumption based on gender.

Keywords: residential water demand, Stone Geary, Oaxaca-Blinder, gender differences
JEL codes: Q21; Q25; D12; D90
Competing interests: The authors have no competing interests to declare that are relevant to the content of this article.

1. INTRODUCTION

Two-thirds of the global population live under conditions of severe water scarcity (Mekonnen and Hoekstra, 2016) and about 2 billion people live in areas suffering from water stress (WMO, 2021). While the causes of water depletion are various (Dolan et al., 2021), this excessive demand for water is unsustainable (He et al., 2021). With that in mind, managing water scarcity is a current challenge for human development and for achieving the UN Sustainable Development Goals (UN, 2015).

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 (García-Valiñas and Suárez-Fernández, 2022). Since water is a basic need, pricing strategies are controversial (Arbués et al., 2003) 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. (2011), Ferraro and Miranda (2013), and Ferraro and Price (2013). Since nudges tend to be more effective when messages are personalized (Schultz et al., 2014; Bernedo et al., 2014), improving the available knowledge on consumer profiles and their consumption patterns will be crucial for efficient policymaking.

Previous studies have argued that women are more environmentally concerned than men (e.g., Dietz et al., 2002; Biel and Nilsson, 2005; Davies et al., 2014). Moreover, gender is also strongly correlated with other variables, creating significant differences in wage levels (e.g., Olivetti and Petrongolo, 2008; 2016; Blau and Kahn, 2017), education and health levels (e.g., Duflo, 2012; Klasen, 2017), or risk, social, and competitiveness preferences (Croson and Gneezy, 2009), among others. All these differences can create variances in water consumption patterns across single-gender households, or households where most water consumption decisions are made by one gender[1].

Water demand analyses tend to overlook the role of gender in water consumption (García-Valiñas and Suárez-Fernández, 2022), finding mixed results. For instance, Mu et al. (1990) concluded that women in developing countries increase water consumption due to a lower opportunity cost in water collection. Considering aggregate regional data, Reynaud (2015) found that water consumption is higher for women, a likely consequence of them devoting more time to water-consuming household chores (Hablemitoglu and Ozmete, 2010; Tong et al., 2017). Horsburgh et al. (2017) 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. (2009) and Davies et al. (2014) 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 (Hablemitoglu and Ozmete, 2010), and they seem to be more environmentally concerned regarding water stress risks (Larson et al., 2011; March et al., 2013). To sum up, the existing literature seems to point towards higher consumption

[1] Grønhøj and Ölander (2007) found that household members tend to specialize in different sub-activities according to their gender.

among women due to better hygiene habits and more intensive household chores, but not due to water-wasting practices.

Recent studies have 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 is proven to lead to inefficient water demand (Wichman, 2014; 2017; Brent and Ward, 2019). This problem is especially true when water consumers face multinomial, non-linear, and block prices, given the complexity of their tariffs (Binet et al., 2014; Brent and Ward, 2019; García-Valiñas et al., 2021). Considering that previous research has shown strong evidence in favor of women being more risk averse than men (Croson and Gneezy, 2009), we should expect women to be more likely to have better information regarding water services.

Finally, the few papers that consider gender when studying household water consumption 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. (2003), Davies et al. (2014) or Tong et al. (2017). On the other hand, when information on the gender composition of each household (or region) is available, as in Reynaud (2015), Garcia et al. (2019) and Grespan et al. (2022), 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 the aforementioned shortcomings in the existing literature. To that end, we studied water consumption patterns and their determinants in single-gender households. We estimated a water demand function for each gender, computing elasticities and calculating the level of conditional water use thresholds separately. Then, 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 the quality of information on water billing data. We also estimated the proportion of water consumption differences not explained by these variables.

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., Gaudin et al. (2001); Martínez-Espiñeira and Nauges (2004); Madhoo (2009); García-Valiñas et al. (2010); Dharmaratna and Harris (2012); Clarke et al. (2017); Hung et al. (2017); Roibás et al. (2019)). 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 (Dharmaratna and Harris, 2012). Furthermore, it presents a parsimonious-enough form to estimate accurate price elasticities without excessive parametrization of the model and yields time- and season-dependent elasticities coherent with previous evidence on water demand (Gaudin et al., 2001). The bimonthly water demand of a given household can be read as

$$W_{it} = \alpha_0 + \sum_{j=1}^{K} \alpha_j X_{ij} + \sum_{t=1}^{T-1} \psi_t D_t + \beta IncPrice_{it} + \varepsilon_{it} \qquad (1)$$

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; 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 (1976) and divided by marginal water prices $IncPrice_{it}$; 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 (Olmstead et al., 2007; Binet et al., 2014):

$$\mathrm{IncPrice} = \begin{cases} \dfrac{\mathrm{I} - \mathrm{F}}{\mathrm{p}_1} \; if \;\; \mathrm{W} \leq \mathrm{b}_1 \\ \dfrac{\mathrm{I} - \mathrm{F} + (\mathrm{P}_3 - \mathrm{P}_1)\mathrm{b}_1}{\mathrm{P}_2} \; if \; \mathrm{b}_1 < \mathrm{W} \leq \mathrm{b}_2 \\ \dfrac{\mathrm{I} - \mathrm{F} + (\mathrm{P}_3 - \mathrm{P}_1)\mathrm{b}_1 + (\mathrm{P}_3 - \mathrm{P}_2)\mathrm{b}_2}{\mathrm{P}_3} \; \mathrm{if\, W} > \mathrm{b}_2 \end{cases} \qquad (2)$$

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.

From (1), the conditional water use threshold equals

$$\gamma_{\mathrm{it}} = \frac{1}{1-\beta}\left(\alpha_0 + \sum_{\mathrm{j}}^{\mathrm{K}} \alpha_{\mathrm{j}} \mathrm{X}_{\mathrm{ij}} + \sum_{\mathrm{t}}^{\mathrm{T}-1} \psi_{\mathrm{t}} \mathrm{D}_{\mathrm{t}}\right) \qquad (3)$$

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 (Gaudin et al., 2001).

On the other hand, price/income elasticities equal

$$\eta_{it}^{p} = -\eta_{it}^{I} = -\beta \frac{\text{IncPrice}_{it}}{W_{it}} \tag{4}$$

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 (Olmstead, 2009; Szabó, 2015). Similar to Pérez-Urdiales et al. (2016), we followed the control function procedure (Wooldridge, 2015). This procedure is similar to the 2SLS estimation, wherein we first estimate the following equation

$$\text{IncPrice}_{it} = \delta_0 + \sum_{j=1}^{K} \delta_j X_{ij} + \sum_{t=1}^{T-1} \lambda_t D_t + \phi_1 P_{1t-1} + \phi_2 P_{1t-2} + \omega_{it} \tag{5}$$

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 (Olmstead, 2009; Szabó, 2015). Since most households from our data sample are located in the first block[2], 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.

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 (Oaxaca, 1973; Blinder, 1973), which is widely used in the field of Labor Economics to analyze wage differentials between subsamples. 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).

$$\begin{aligned} E(W_F) - E(W_M) = \\ \underbrace{\sum_{j=1}^{K} \widehat{\alpha_j^*}\left[E\left(X_{jF}\right) - E\left(X_{jM}\right)\right] + \widehat{\beta^*}\left[E(IncPrice_F) - E(IncPrice_M)\right]}_{Explained\ Part} \\ \underbrace{+ \widehat{\alpha_{0F}} - \widehat{\alpha_0^*} + \sum_{j=1}^{K} \left(\widehat{\alpha_{jF}} - \widehat{\alpha_j^*}\right) E\left(X_{jF}\right) + \left(\widehat{\beta_F} - \widehat{\beta^*}\right) E(IncPrice_F)}_{\text{Women Unexplained Part}} \end{aligned} \tag{6}$$

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

$$+\widehat{\alpha_0^*} - \widehat{\alpha_{0M}} + \underbrace{\sum_{j=1}^{K} \left(\widehat{\alpha_j^*} - \widehat{\alpha_{jM}}\right) E\left(X_{jM}\right) + \left(\widehat{\beta^*} - \widehat{\beta_M}\right) E(IncPrice_M)}_{\text{Men Unexplained Part}}$$

where $\widehat{\alpha_0^*}$, $\widehat{\alpha_j^*}$ and $\widehat{\beta^*}$ are the estimated parameters from a pooled regression of both subsamples with a dummy regressor identifying gender. This method follows Neumark (1988), Oaxaca and Ransom (1994), and Jann (2008), who advocated for the use of non-discriminating parameters to avoid the "index number problem" that arises when reference parameters are chosen on an ad hoc basis (Blinder, 1973).

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). Information regarding real bimonthly water consumption and its marginal prices was obtained from the water supplier in Gijón, public company EMA (*Empresa Municipal de Aguas*). Family 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[3].

The database covers 275 single-gender households[4] with individual water meters, spanning 28 periods between 2017 and the first six months of 2021. For each household type, there are 169 households of women (4,123 observations) and 106 households of men (2,856 observations).

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 €2,701-3,700. Following Carlevaro et al. (2007) and Binet et al. (2014) in the context of water demand, we obtained a continuous variable for household disposable income after accounting for fixed charges for water consumption and the adjustment made using Nordin's difference (see Subsection 3.1). To do so, we followed the procedure outlined by Manski and Tamer (2002) and van Doorslaer and Jones (2003) and conducted a regression analysis to explain income, taking into account household and socioeconomic family characteristics[5].

---

[3] For further information, please visit https://observa.gijon.es/pages/inicio.
[4] Initially, 6,800 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 1,068 single- and mixed-gender households.
[5] Further details can be found in Appendix B.

Table 1. Variables and their definitions.

Variable	Name	Definition
W	Water consumption	Household bimonthly consumption in each billing period (m3)
Inc	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 (€)
IncPrice	Real income	Net income divided by water marginal prices (Inc/P)
Men	Household of men	Dummy variable: 1 if all the members of a household are men
Memb	Household members	Number persons living in the surveyed household
Old_65	Share of seniors	Proportion of household members older than 65 (%)
Yng_18	Share of minors	Proportion of household members younger than 18 (%)
Work	Share of employed	Proportion of household members employed or self-employed (%)
Coll	Share of educated	Proportion of household members with tertiary education or higher (%)
Old_H	Old house	Dummy variable: 1 if residence is over 40 years old
Gard	Owning a garden	Dummy variable: 1 if residence has a garden
Pool	Owning a swimming pool	Dummy variable: 1 if residence has a swimming pool
Dish	Owning a dishwasher	Dummy variable: 1 if residence has a dishwasher
Eff_Dev	Index of efficient devices	Share of water-saving devices in residence
Eff_Appl	Index of efficient appliance	Share of water and energy-saving appliances in residence
Wat_Hab	Good water-saving habits	Dummy variable: 1 if the respondent declares having more than 6 of the 13 habits
Camp	Aware of water saving campaign	Dummy variable: 1 if remembers a water-saving campaign implemented during the last five years
Unk_Bill	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
Under_Bill	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

The water prices in Gijón follow an increasing block tariff (IBT) (see Table 3). Accordingly, marginal prices follow a three-block increasing structure, increasing by cubic meters of water consumption. 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 located 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[6]. 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[7].

Table 2. Main statistics.

	Total (N=7,319)		**Men (N=2,856)**		**Women (N=4,463)**	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
W	11.277	10.428	10.591	9.233	11.716	11.104
Inc	3141.190	1219.700	3167.318	1213.744	3124.469	1223.338
Price	1.016	0.139	1.012	0.131	1.018	0.143
Inc_Price	3315.24	2170.297	3355.967	2177.026	3289.177	2165.822
Men	0.390	0.488	-	-	-	-
Memb	1.346	0.621	1.250	0.455	1.407	0.700
Old_65	40.725	46.666	32.353	45.73	46.083	46.476
Yng_18	2.778	11.284	3.105	12.512	2.569	10.42
Work	42.267	45.829	48.699	47.551	38.151	44.209
Coll	18.577	36.309	18.487	36.883	18.635	35.94
Old_H	0.617	0.486	0.536	0.499	0.669	0.471
Gard	0.111	0.314	0.137	0.344	0.094	0.292
Pool	0.019	0.137	0.02	0.139	0.019	0.136
Dish	0.431	0.495	0.452	0.498	0.417	0.493
Eff_Dev	16.010	21.347	20.579	23.829	13.085	19.030
Eff_Appl	46.673	39.808	51.278	38.822	43.726	40.154
Wat_Hab	0.895	0.307	0.922	0.269	0.877	0.328
Camp	0.391	0.488	0.472	0.499	0.34	0.474
Unk_Bill	0.277	0.448	0.25	0.433	0.294	0.456
Under_Bill	3.003	13.622	5.401	18.403	1.468	9.034
Zero	0.025	0.157	0.029	0.169	0.023	0.149

According to previous works, the impact of household income on water consumption is expected to be positive, while marginal prices should decrease consumption, with both income and price elasticities of demand inferior to one (Arbués et al., 2003; Worthington and Hoffman, 2008; Nauges and Whittington, 2010; Reynaud, 2015; García-Valiñas and Suárez-Fernández, 2022). This would confirm water is a necessity good, with a

[6] All variables are net of taxes.
[7] 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

diminishing relative weight on household expenditure as income increases, and a demand quite insensitive to changes in water prices.

Table 3. Water marginal 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

Source: Own elaboration using data from BOPA núm. 300 de 30-xii-2014, núm. 248 de 27-xii-2019, núm. 175 de 29-VII-2014

The remaining explanatory variables of the Stone-Geary demand function are commonly found in the previous literature (e.g., Worthington and Hoffman, 2008; García-Valiñas and Suárez-Fernández, 2022).

- **Family socioeconomic characteristics:** We considered several factors related to family socioeconomic characteristics. These include the number of household members, age composition taking into account the proportion of older people and minors, and employment status and education level, which include 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, houses with gardens, houses with swimming pools, and houses with dishwashers. To summarize the information about investment in efficient household devices and appliances, we included the variable Eff_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 Eff_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 of these appliances.
- **Water-related household information:** We constructed the dummy variable Wat_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[8]. Additionally, we included the dummy variable

[8] 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

Campaign to account for households that are aware of any campaigns to promote water saving. Regarding household information on water bills, we have two groups of information: first, when the respondent overestimates, underestimates, or does not know the amount of the water bill; and second, the percentage level of over- or underestimation. The first group consists of three dummy variables. Over_Bill takes a value of 1 when the respondent overestimates the water bill, Under_Bill takes a value of 1 when the respondent underestimates the water bill, and Unk_Bill takes a value of 1 when the respondent does not know or does not provide information about the water bill. The second group consists of two continuous variables. Prop_Over represents the percentage of overestimation of the water bill, while Prop_Under represents the percentage of underestimation.

Table 2 presents the descriptive statistics of the database for single-gender households, distinguishing between men and women. As shown in Table 2, average water consumption is higher for women than for men, with consumption levels of 11.76 m^3 and 10.64 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 family members, with an average of 1.41 compared to 1.25 family members in men's households. Regarding family composition, a larger proportion of men are younger 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 informed about their water bills (25% compared to 30% of informed women) and, on average, they underestimate their bill charges by 5.4%, whereas women's underestimation is only 1.5%.

3. RESULTS AND DISCUSSION

3.1. *Stone-Geary demand function by gender.*

Table 4 presents the estimates of the Stone-Geary demand function for men, women, and the pooled sample. To address the endogeneity issue associated with corrected income divided by marginal prices, we used the Control Function procedure from Wooldridge (2015). Following the approach of Pérez-Urdiales et al. (2016), we used the full set of marginal prices as instruments (see Appendix A for details). According to the estimations in Table 4, we observed that the coefficients were robust across the subsamples. Water demand increases with income and decreases with marginal prices, as predicted by the theory. Focusing on gender differences, a preliminary result from the overall sample indicated that men's households exhibit higher water consumption compared to women's households after accounting for other factors, as shown in the pooled regression, column 1 of Table 4.

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.

Table 4. Stone-Geary demand function.

Variable	Pooled		Women		Men	
Inc_Price	0.000***	(6.35)	0.000***	(3.87)	0.001***	(7.19)
Memb	8.171***	(42.11)	8.738***	(39.31)	4.980***	(11.12)
Old_65	0.019***	(5.55)	0.019***	(3.97)	0.005	(0.98)
Yng_18	-0.147***	(-14.57)	-0.099***	(-6.78)	-0.134***	(-9.16)
Work	-0.016***	(-4.52)	-0.016***	(-3.15)	-0.019***	(-3.85)
Coll	-0.009***	(-2.76)	-0.009*	(-1.89)	-0.015***	(-3.09)
Old_H	1.387***	(5.48)	2.237***	(6.00)	1.074***	(3.09)
Garden	1.719***	(4.50)	0.571	(1.05)	2.947***	(5.60)
Pool	9.723***	(11.86)	5.195***	(4.36)	16.958***	(14.44)
Dish	1.911***	(7.43)	3.147***	(8.91)	1.164***	(3.12)
Eff_Dev	0.019***	(3.61)	-0.031***	(-3.97)	0.064***	(9.42)
Eff_Ap	-0.020***	(-6.30)	-0.029***	(-6.87)	-0.002	(-0.49)
Wat_Hab	-1.457***	(-4.45)	-0.981**	(-2.42)	-2.690***	(-4.69)
Camp	-0.455**	(-2.12)	-0.599**	(-2.10)	-1.784***	(-5.15)
Unk_Bill	-0.618***	(-2.72)	-0.446	(-1.47)	-1.291***	(-3.54)
Prop_Under	0.088***	(11.80)	0.087***	(5.87)	0.076***	(9.29)
Zero	-10.918***	(-17.05)	-11.941***	(-13.58)	-8.827***	(-10.02)
Men	0.518**	(2.44)				
Residual	-0.004***	(-25.50)	-0.005***	(-20.49)	-0.004***	(-16.89)
Constant	-0.163	(-0.22)	-1.455	(-1.48)	4.891***	(4.29)
N	6,766		4,123		2,643	
adj. R2	0.407		0.457		0.384	

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

- **Family socioeconomic characteristics:** Continuing with other socio-economic determinants, household size was found to increase water demand, which is consistent with previous findings in the literature (Schleich and Hillenbrand, 2009; García-Valiñas et al., 2010; Binet et al., 2014; Pérez-Urdiales et al., 2016; Hoyos and Artabe, 2017; Hung et al., 2017; Roibás et al., 2019). On one hand, the percentage of household members under 18 years old residing in the household reduces the amount of water consumed, similar to the effect of children found in Hoyos and Artabe (2017). On the other hand, households with higher proportions of people over 65 increase the water demand for women, as observed in Schleich and Hillenbrand (2009), who found that older individuals consume more water. However, for men, this variable is not statistically significant. Moreover, employment status also accounts for household water consumption patterns. As employed individuals typically spend less time at home, households with a higher proportion of employed members tend to exhibit lower levels of water consumption, as in Binet et al. (2014). Regarding education level, households with a higher proportion of highly educated individuals tend to consume less water, probably due to greater environmental awareness, as seen in Gilg and Barr (2006).
- **Housing characteristics:** We found that owning older houses is associated with higher water consumption, possibly due to a higher likelihood of leakages (Nauges and Thomas, 2000; García and Reynaud, 2004). Consistent with previous studies, owning a garden for men or a swimming pool for both genders significantly increases domestic water demand (Agthe and Billings, 1987; García-

Valiñas et al., 2013; Binet et al., 2014; Jayarathna et al., 2017). Furthermore, owning a dishwasher also contributes to higher levels of water consumption. Although dishwashers are considered efficient appliances (Pérez-Urdiales and García-Valiñas, 2016), their water-saving potential depends on proper usage, such as running them when fully loaded (Martínez-Espiñeira et al., 2014). The proportion of efficient devices installed in the household decreases water consumption in women's households, 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 (2019). Regarding specific water-saving equipment, measured by the index of efficient dishwashers and washing machines, we found it to be significant and to exhibit the expected negative sign for women's households, consistent with previous studies (Renwick and Green, 2000; García-Valiñas et al., 2013; Pérez-Urdiales and García-Valiñas, 2016; Rathnayaka et al., 2017), while its effect is not significant for men.

- **Water-related household information**: As expected, having efficient water consumption habits and being aware of a water-saving campaign reduces water demand. Rajapaksa et al. (2019) demonstrated that promoting pro-environmental behaviors results in significant reductions in water consumption. Regarding knowledge of water bills, the variable is positive and significant 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. (2014), who observed that individuals tend to increase water consumption when they underestimate marginal prices, as well as with Rajapaksa et al. (2019), 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 (2017) and Brent and Ward (2019), as increased consumption can be attributed to inefficient demand decisions. Regarding reported bill knowledge, men's households that lack information about their water bills exhibit significantly lower levels of water demand.

We computed mean price elasticities and calculated the conditional water use threshold (Gaudin et al., 2001) for women and men with the results displayed in Table 5. We observed that water demand is more inelastic for women (0.18) as compared to men (0.37), while the level of conditional water use threshold is higher for women than for men (10.37 and 8.07, respectively).

After controlling for all the observed variables included in the analysis, in Table 4 we can see that men's households consume more. In order to gain a deeper understanding of the effects of gender on household water consumption, we conducted an Oaxaca-Blinder decomposition.

Table 5. Estimated conditional water use threshold and price elasticity.

	Women	**Men**	**Diff t-test**
Threshold	10.3700	8.0743	-2.2957***
Price elasticity	-0.1821	-0.3664	0.1843***

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

3.2. *Oaxaca–Blinder decomposition for gender differences in water demand.*

According to Table 6, differences in average water consumption between genders are statistically significant at the 1% level, showing that households formed by women (our reference group) consume more water than those formed by men (see overall coefficients for women, 11.760, and men, 10.643). More precisely, women's households consume 1.117 additional cubic meters with respect to men.

Using the Oaxaca-Blinder decomposition, the overall differences in consumption can be separated into two parts: first, an "explained" part, which is due to differences in observable characteristics, providing an economic explanation for gender differences; and second, an "unexplained" part, which is due to differences in coefficients and unobserved variables.

As shown in Table 6, the explained part of the Oaxaca-Blinder decomposition is statistically significant at the 1% level and contributes to increasing differences between genders by 146%[9]. This means that gender differences in household water consumption are primarily due to differences in the observable characteristics included in our analysis, either due to household characteristics increasing women's consumption or reducing men's consumption.

Since we conducted the threefold decomposition, the unexplained part is divided into differences between the pooled regression and the women's regression, and also with respect to the men's regression. In Table 6 we can see that the coefficients are statistically different between pooled and men's regressions at the 1% level, but we found no significant differences with respect to women's regression[10]. The unexplained part with respect to men's households contributes to reducing the differences between men' and women's households by 46%, making men consume more[11].

3.3. *Explained part of gender water consumption differences.*

Exploring the determinants of the explained part of water consumption differences (see Explained in Table 6), 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 (Table 4) and women are the reference group for the Oaxaca-Blinder decomposition (Table 6).

[9] This result has been calculated by dividing the explained part, 1.634, by the total difference, 1.117.
[10] This could indicate that there might be other unobserved variables explaining the remaining differences between water consumption of women and men.
[11] Note that the value -0.518 corresponds to the coefficient of the dummy variable males in the pooled regression in Table 7.

Table 6. Oaxaca-Blinder decomposition of water consumption by gender.

Overall differences						
Inc_Price	11.760***			(67.94)		
Memb	10.643***			(58.51)		
Old_65	1.117***			(4.45)		
Yng_18	1.634***			(8.14)		
Work	0.000			(0.00)		
Coll	-0.518***			(-2.65)		
	Explained		**Unexplained women**		**Unexplained men**	
Inc_Price	-0.031	(-1.16)	-0.157	(-0.42)	-0.993**	(-2.01)
Memb	1.284***	(8.86)	0.798***	(3.99)	3.991***	(4.31)
Old_65	0.266***	(5.38)	-0.024	(-0.18)	0.468***	(3.71)
Yng_18	0.083*	(1.91)	0.122***	(4.21)	-0.039	(-0.69)
Work	0.171***	(4.22)	0.008	(0.06)	0.124	(0.73)
Coll	-0.001	(-0.15)	0.009	(0.14)	0.108	(1.29)
Old_H	0.187***	(4.65)	0.570***	(3.09)	0.168	(0.82)
Garden	-0.075***	(-3.19)	-0.108***	(-2.67)	-0.169**	(-2.43)
Pool	-0.007	(-0.22)	-0.086**	(-2.52)	-0.142***	(-2.67)
Dish	-0.069***	(-2.71)	0.515***	(4.86)	0.338**	(2.49)
Eff_Dev	-0.140***	(-4.26)	-0.647***	(-10.29)	-0.933***	(-8.59)
Eff_App	0.153***	(4.27)	-0.390***	(-2.92)	-0.903***	(-3.18)
Wat_Hab	0.065***	(3.85)	0.418**	(2.25)	1.135***	(2.91)
Campaign	0.060**	(2.27)	-0.049	(-0.80)	0.629***	(4.59)
Unk_bill	-0.028**	(-2.40)	0.051	(0.95)	0.169**	(2.25)
Prop_Under	-0.349***	(-5.41)	-0.001	(-0.03)	0.067	(1.53)
Zero	0.066	(1.53)	-0.023**	(-2.43)	-0.059***	(-3.82)
Residual	0.000	(0.00)	0.000	(0.00)	0.000	(0.00)
Constant	-	-	-1.293**	(-2.20)	-5.054***	(-4.98)

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

The coefficients of the Oaxaca-Blinder explained part can be interpreted as follows. On the one hand, a positive sign in the pooled regression (Table 4) is some household characteristic that increases consumption and a positive sign in the explained part (Table 6) is a household characteristic that increases gender differences[12]. On the other hand, a negative sign in the pooled regression is some characteristic that reduces household consumption and a negative sign in the explained part is a characteristic that decreases gender differences.

Accordingly, we have four sets of results:

1. Household characteristics that increase differences due to higher consumption among women. The most relevant is household size, which increases the explained differences by 79%, as women's households are large enough to lead to higher average water consumption as compared to men's households. Other

[12] Note that since the reference consumption is that of women's households, bigger gender differences could be due to either higher consumption among women or to lower male consumption.

relevant characteristics are a higher percentage of seniors (16%) and having older houses (11%).

2. Household characteristics that increase differences due to lower consumption among men. Households formed by men have a higher share of employed and minor members, as well as more efficient appliances. Along the same line, men report having better water use habits and being more aware of water saving campaigns than women.
3. Household characteristics that reduce differences due to higher consumption among men. The most important characteristic is having a higher index of bill underestimation (21%). In addition, men's houses tend to be endowed with gardens, dishwashers, and efficient devices, which narrow the explained differences in water consumption between genders.
4. Household characteristics that reduce differences due to lower consumption among women. None of the considered characteristics show this kind of effect.

3.4. *Unexplained part of gender water consumption differences.*

Exploring the differences between the coefficients of the pooled regression and the regressions for women and for men (see Unexplained in Table 6), we observed that many characteristics have different effects for men than for the pooled sample. The coefficients of the Oaxaca-Blinder unexplained part can be interpreted as follows:

1. Characteristics that increase water consumption whose marginal effect is higher for the pooled sample than for men's households include the number of family members, the proportion of seniors, and having a dishwasher. This can be interpreted as men's water consumption being less sensitive to bigger and older families and to having dishwashers as compared to the pooled sample.
2. Characteristics that increase water consumption whose marginal effect is higher for men's households than for the pooled sample include having a garden, pool, or efficient devices. The interpretation is that the physical features of the house are especially relevant for men's households. In the same line, higher household earnings have a greater effect for men than for the pooled sample.
3. Characteristics that reduce consumption whose marginal effect is higher in the men's regression than for the pooled sample include having good water habits, being aware of water saving campaigns, and being uninformed about water bills. According to this result, men's households are more sensitive to characteristics related to water savings compared to the pooled households sample.
4. Characteristics that reduce consumption whose marginal effect is higher in the pooled regression than for the men's households are having efficient appliances.

4. CONCLUSION

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 family members, and presence of a garden or swimming pool (see, for example, Makki et al. (2015); Arbués et al. (2010); Garcia-Valiñas et al. (2014);

Renzetti et al. (2015); or Hoyos and Artabe (2017)). 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 family members, or the gender of the head of household (Reynaud, 2015; Kayaga et al., 2003; Grespan et al., 2022).

In this paper, we had the unique advantage of accurately identifying gender differences in residential water consumption by focusing our analysis exclusively on 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 29 bimesters, covering the period from 2017 to 2021.

Firstly, 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 households led by women tend to consume more water compared to households led by men, which is in line with previous studies by Horsburgh et al. (2017) and Reynaud (2015). 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 family members, a higher proportion of elderly individuals, physically older houses, and reporting poorer water-saving habits and lower awareness about conservation campaigns as compared to men's households.

These findings have significant public policy implications. The role of information is crucial to improve water use efficiency at the residential level. Both inattention and lack of knowledge about water prices can generate significant water waste across residential consumers. This fact highlights the need to develop public informative and/or educational campaigns to improve the quality and quantity of information that households have on both consumption and water prices.

On the one hand, water bills should be properly designed to be transparent and promote the understanding of all water tariff components. Moreover, both academic and institutional forums (Arbués and García-Valiñas, 2020) strongly recommend reducing the complexity of water tariffs and making them more transparent.

On the other hand, nudging (Thaler, 2018) or boosting (Grüne-Yanoff, 2018) strategies could contribute to substantially improving the awareness and knowledge of households around water issues. By means of social comparison tools, conservation goals, and/or financial information, households could become aware of key dimensions and behave more efficiently in certain situations (Brent and Ward, 2019; Brent et al. 2020). Definitively, this kind of informational policy should be used in combination with more traditional tools such as water tariffs in order to improve water use efficiency.

Furthermore, our results show that these nudging strategies should first be aimed at men. The Oaxaca-Blinder decomposition proves that not only do men have worse water-saving habits, as well as worse information about their water invoices, but they are also more sensitive to changes in these variables. Therefore, informative campaigns directed at men are expected to lead to higher initial reductions in excessive water consumption to a certain extent. Nevertheless, providing women with better information must not be ignored in the long term since, due to the limitations of our study, we cannot affirm that women's households are the benchmark in terms of efficient residential water demand.

FUNDING

This research was funded by the European Commission in the frame of the collaborative international consortium financed under the 2018 Joint call of the WaterWorks2017 ERA-NET Cofound.

ACKNOWLEDGMENTS

The authors would like to thank the European Commission for funding in the frame of the collaborative international consortium financed under the 2018 Joint call of the WaterWorks2017 ERA-NET Cofound. This ERA-NET is an integral part of the activities developed by the Water JPI.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Arbués, F., & García-Valiñas, M. (2020). Water tariffs in Spain. Oxford Research Encyclopedias.

Biel, A., & Nilsson, A. (2005). Religious values and environmental concern: Harmony and detachment. Social Science Quarterly, 86(1), 178-191.

Binet, M. E., Carlevaro, F., & Paul, M. (2014). Estimation of residential water demand with imperfect price perception. Environmental and Resource Economics, 59, 561-581.

Blau, F. D., & Kahn, L. M. (2017). The gender wage gap: Extent, trends, and explanations. Journal of economic literature, 55(3), 789-865.

Brent, D. A., & Ward, M. B. (2019). Price perceptions in water demand. Journal of Environmental Economics and Management, 98, 102266.

Brent, D. A., Lott, C., Taylor, M., Cook, J., Rollins, K., & Stoddard, S. (2020). What causes heterogeneous responses to social comparison messages for water conservation?. Environmental and Resource Economics, 77, 503-537.

Croson, R., & Gneezy, U. (2009). Gender differences in preferences. Journal of Economic literature, 47(2), 448-474.

Dietz, T., Kalof, L., & Stern, P. C. (2002). Gender, values, and environmentalism. Social science quarterly, 83(1), 353-364.

Duflo, E. (2012). Women empowerment and economic development. Journal of Economic literature, 50(4), 1051-1079.

García-Valiñas, M. Á., Martínez-Espiñeira, R., & Suárez-Varela Maciá, M. (2021). Price and consumption misperception profiles: The role of information in the residential water sector. Environmental and Resource Economics, 80, 821-857.

Grüne-Yanoff, T. (2018). Boosts vs. nudges from a welfarist perspective. Revue d'économie politique, (2), 209-224.

Klasen, S. (2017). Gender, institutions, and economic development. The handbook of economic development and institutions.

Mu, X., Whittington, D., & Briscoe, J. (1990). Modeling village water demand behavior: a discrete choice approach. Water Resources Research, 26(4), 521-529.

Olivetti, C., & Petrongolo, B. (2008). Unequal pay or unequal employment? A cross-country analysis of gender gaps. Journal of Labor Economics, 26(4), 621-654.

Olivetti, C., & Petrongolo, B. (2016). The evolution of gender gaps in industrialized countries. Annual review of Economics, 8, 405-434.

Reynaud, A. (2015). Modelling household water demand in Europe–insights from a cross-country econometric analysis of EU-28 countries. Insights from a cross-country econometric analysis of EU, 28.

Thaler, R. H. (2018). From cashews to nudges: The evolution of behavioral economics. American Economic Review, 108(6), 1265-1287.

Wichman, C. J. (2014). Perceived price in residential water demand: Evidence from a natural experiment. Journal of Economic Behavior & Organization, 107, 308-323.

Wichman, C. J. (2017). Information provision and consumer behavior: A natural experiment in billing frequency. Journal of Public Economics, 152, 13-33.