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Alternative tariff structures and household composition: Evidence from Spain's Valencia region

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ABSTRACT

Water pricing is one of the fundamental tools for water resources management. However, the current tariff structure in Spain has associated problems in relation to the composition of households. This paper analyses the current tariffs of Spain's Valencia region and studies the effect of alternative tariff structures. The results show an imbalance irrespective of the tariff applied even when the number of household members is considered, as the relationship between the number of household members and water consumption is not linear. Therefore, the problem is not the tariff structure per se but not including the composition of the household in the tariff.

1. Introduction

Water resources are one of the central aspects of our society, so their proper management is essential for human activity to be sustainable. The services we obtain from these resources are vital and varied, so designing an efficient water policy can be very challenging. This problem is amplified in the current context, where climate change has the potential to severely affect the functioning of the various water services we enjoy (Yoo et al., 2014). Climate change calls for a more resilient system with tariffs that are compatible with environmental, social and financial sustainability and that pursue economic efficiency of water services (Marques and Miranda, 2020; García-Rubio et al., 2015), which requires as much information as possible (Corbella and Pujol, 2009). For example, Water supply requires a certain amount of energy consumption due to water treatment and distribution, which affects both the financial and environmental costs of supply and consequently conditions the design of tariffs and the information needed. (Melgarejo et al., 2016). Water resources management may not be sustainable if it fails to recover its costs from its revenues (EU, 2000; Tardieu and Préfol, 2002). These costs may increase in the future, as one of the axes of water policy is water quality, and this may be reduced due to our activity, so proper management of resources today would allow us to prevent an increase in costs (McDonald et al., 2016). Water pricing is an essential tool for raising the revenues needed to keep the activity running and influencing consumption patterns (Zetland and Gasson, 2013). However, the tariff is not only a source of revenue; it is also a tool to communicate the scarcity situation of water resources. However, the tariff must be adequately communicated to consumers to have the desired effect, or it will only be perceived as a price in exchange for a service (Gaudin, 2006). There are public services in which their rates are not necessarily justified by the scarcity or cost the same; some public authorities can use a public service as an argument to collect a tax above its cost.

Moreover, this price has to be affordable to citizens; otherwise, the measure will not be publicly accepted, and its effectiveness will be reduced (Alcon et al., 2012). In terms of demand management, prices are not the only measure available (Rey et al., 2019), but competitive prices are more efficient than other forms of allocation, such as rationing policies (Grafton and Ward, 2008). However, for a pricing policy to be efficient, it must be accompanied by additional measures to raise awareness and inform consumers (Zikos, 2008; García-Rubio et al., 2015).

Adequate revenue generation to achieve water policy objectives and resource sustainability is crucial. However, pricing policy has many other effects that should be taken into account (Rogers et al., 2002). Thus, high prices discourage over-consumption, soften scarcity and provide funds to improve water policy and thus water services (Zetland and Gasson, 2013), although the financial situation of water users must continually be assessed in order to not over-price water, i.e., the issue is to meet the above objectives while avoiding burdening users with a higher price than necessary to finance the service, which would mainly affect low-income households (Reynaud, 2016) or users for whom water is a productive resource, such as farmers (Tardieu and Préfol, 2002). For this reason, the Water Framework Directive (WFD) allows for setting aside some environmental objectives when the economic cost of

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achieving them is excessive (Alcon et al., 2012). Therefore, it is essential to consider in the design of the revenue formula that the user will react to price changes, as it gives an uncertainty component to revenue generation, which can affect the overall result of a price policy (Opaluch, 1984). In this sense, as already mentioned, how users are informed of the tariff to which their consumption will be subjected will condition not only their opinion of the price but also their reaction to it, which affects the public acceptance of the tariff and the revenues obtained (Gaudin, 2006). Such communication could be done by conveying to citizens the costs of the service and how the revenues from their water consumption are used so that user engagement can be obtained (Smith and Walker, 2019). This approach is in addition to the fact that the determinants of consumption are varied and their interaction complex (Corbella and Pujol, 2009), so minimising uncertainty related to users' perceptions can be beneficial.

In summary, the main objective of water tariffs is to finance water supply services efficiently and equitably (Suárez-Varela, 2020). However, this is a complex objective, as the various effects of water prices must be taken into account, including their influence on supply and demand, the distribution of water resources, the quality of water management and the financial situation of households (Rogers et al., 2002). On the other hand, we must also consider that some of the revenues from water are not public prices as such but are taxes that seek to apply the "polluter pays" principle by obtaining funds to correct damages caused in the development of the activities that we carry out (García-Valiñas and Arbués Gracia, 2020). In other words, the revenue system of water services is complex and requires in-depth analyses to design efficient revenue-raising formulas (Ruijs, Zimmermann & van der Berg, 2008).

As mentioned, water revenues must take into account the particularities of each case (Melgarejo et al., 2016; Plappally and Lienhard, 2013; Stoker and Rothfeder, 2014; Corbella and Pujol, 2009), which can lead to low prices in order not to apply too much pressure on household budgets (Reynaud, 2016). This practice, in turn, could lead to high consumption and pressure on resources (Zetland and Gasson, 2013), leading to the relatively costly development of unconventional water sources and needing new financial revenues (Ipe and Bhagwat, 2002; McDonald et al., 2016). One of the most complex aspects a tariff must address to meet its objectives is the consumer's relationship with price and consumption. Thus, the consumer does not always react in the same way to price, but there is a stage where the relationship is linear, but once the necessary consumption is covered, the relationship becomes exponential because, at that point, the consumer's objective is to reduce their bill (Huang et al., 2021). Thus, the effectiveness of the tariff in influencing consumption is reduced until the necessary consumption is reached, so up to this point, the tariff is mainly a source of revenue (Gaudin et al., 2001; Martínez-Espiñeira and Nauges, 2004). Unfortunately, this is very difficult to include in a tariff, as consumer behaviour varies from place to place. In any case, the current Spanish structure of tariffs, whether linear or in increasing steps, presents the main problem that they do not consider the composition of households, a problem that can be summarised in two effects (Arbués et al., 2010). The first is that smaller households pay a very high fixed cost for water supply compared to large households. The second refers to the higher speed at which a larger household moves through the tariff brackets so that, without necessarily consuming irresponsibly, the price of water grows faster than for other households (Mansur and Olmstead, 2012). Linear tariffs, moreover, do not discourage excessive consumption in the same way as increasing tariffs. It is, therefore, of great interest to assess the adequacy of current tariffs and the possibility of making changes to their structure. Pricing should also be accompanied by improvements in the communication of tariffs to water users (Gaudin, 2006). Alternative modifications such as seasonal tariffs (Renzetti, 1992) or even tariffs that vary continuously based on recent information (Suárez-Varela, 2020) could also be considered. These possible modifications would allow fares to reflect the actual situation.

Today, increasing-block and linear rates are the most common (Damkjaer, 2020), so the structural problem is present in much of the world. In Europe, while most households need less than 3% of their income to pay for the water supply, some subsidized or special tariffs are often given to households with low incomes or in special situations of economic vulnerability (Reynaud, 2016). However, in Spain, despite the underfunding of water services, households are far from paying 3% of their income on water bills (Arbúes et al., 2004; García-López et al., 2020). The percentage of the rent paid for the water bill is very important, as it is related to the financing of the service, the rest of the household expenses, and, of course, the household income. Even in this situation, a simple increase in tariffs in increasing steps may not be the most appropriate alternative (Dahan and Nisan, 2007), as the reaction of users may cause revenues not to evolve as expected (García-López et al., 2020). Thus, it would be advisable to analyse the adequacy of the current structure and assess the possibility of modifying it to improve the financing of the service and induce efficiency and equity in the system (Martin and Wilder, 1992; Huang et al., 2021; Marques and Miranda, 2020). In Spain, moreover, we find large differences in revenues and taxes related to water services between regions (García-López and Montano, 2020; García-Valiñas and Arbués Gracia, 2020; García-Valiñas and Arbués, 2021). In other words, the context of water services revenues in Spain is one of lack of cost recovery (Suárez-Varela, 2020), territorial differences (García-López and Montano, 2020; García-Valiñas and Arbués, 2021), and the problems derived from increasing-block rates (Arbués et al., 2010). Therefore, significant modifications are needed to address the existing problems, always bearing in mind that users' proper perception of tariffs is crucial (Vatn, 2010; Smith and Walker, 2019; Zikos, 2008).

However, research usually focuses on other issues such as the current problem of the water supply tariffs or the effects of a price increase and therefore does not provide in-depth contributions to improve the tariff structure due to the difficulty of this change. This paper fills this gap by analysing the current tariff structure, other tariff structures and the fundamental aspect that limits the effectiveness of tariffs, such as household composition. This paper works with household-level data from the Region of Valencia (Spain) to generate practical knowledge for the future design of alternative tariffs. Therefore, this analysis provides helpful information on the problem of not considering the structure of households and the possibility of structural changes in tariffs. Thus, after this introduction, the data used and the methodology followed are be explained, the results are be presented, and the discussion generated and the conclusions obtained are be shown.

2. Data and methodology

2.1. Data

The data used are from the Household Budget Survey of the Spanish National Statistics Institute (INE for its Spanish acronym). Thus, this is not a survey focused on water resources, but as the water bill is one of the household expenses, the survey allows us to have water consumption and water expenditure of households. In addition, we can also use other elements such as household income and its composition, as well as population density and the size of the municipality in which households are located. The water consumption variables are measured in cubic metres per year, the household income and water price variables are measured in thousand euros per year and euros per year, respectively, and the proportion of the bill on household income is calculated as a percentage. It should be noted that the price variable only includes the water supply tariff, as water treatment payments are part of a variable that contains other sanitation charges that are not part of water services. The municipality's population density has three values, low, medium and high. Finally, the size of the municipality is divided into several categories: 1) less than 10,000 inhabitants; 2) between 10,000 and 20,000 inhabitants; 3) between 20,000 and 50,000 inhabitants; 4) between 50,000 and 100,000 inhabitants; and 5) more than 100,000 inhabitants.

The sample used corresponds to the 2019 edition of the Household Budget Survey, which contains data from 2018. Since water tariffs vary significantly between regions, only the information relating to the Region of Valencia is used in this analysis in order to avoid problems related to territorial differences.

In addition, outliers have been removed based on several criteria to eliminate observations far from the mean. Firstly, households with a consumption per household of more than 1000 cubic metres or 400 cubic metres per person per year have been eliminated. Secondly, households with a total bill of more than €1000 per year or more than €400 per person per year have also been eliminated. Of course, restricting the sample to the Region of Valencia means discarding a large part of the sample, but the various criteria for eliminating observations only involve eliminating 14 observations, leaving a sample of 1612 households. The 14 households eliminated show, on average, a consumption per household of 537.46 cubic metres and a consumption per person of 406.87 cubic metres, 1.5 household members, a unit price of 1.53€, a monthly income of 2246.93€ and a bill-to-income ratio of 3.17%. These consumption values and the proportion of bills over income are very far from those of the rest of the households, which is why they have been eliminated from the calculations. Therefore, a large part of the sample is retained despite the eliminations applied. It should be noted that the survey observations are associated with a sample weight taken into account in the calculations.

2.2. Methodology

The data used are treated in three main ways. As a first stage, descriptive data about the main variables of the analysis is shown. Based on the results of the first stage, the econometric technique of Ordinary Least Squares (OLS) with robust errors is used to generate four estimations, each of which tries to explain a different variable. Thus, four estimations are presented to analyse the consumption per household, the consumption per person, the unit price and the weight of the bill on the income based on the following equation:

$$X_h = Y_h\beta + \varepsilon_h \tag{1}$$

Categorical variables included in the models refer to the smallest size category as “low” in the case of town population density and “less than 10,000 inhabitants” in municipality size. It is necessary to note that water consumption and price are included in logarithms in the models explaining consumption and price so that the price coefficient can be interpreted as the price elasticity of demand. However, as the estimation to explain the weight of the water bill in household income is not related to the price elasticity, neither price nor consumption are included on a logarithmic scale in this case.

On the other hand, once the above estimations have been made, the methodology consists of two activities. First, descriptive information about the eight household typologies is obtained. Based on this information (average consumption per household, consumption per person and unit price), alternative tariffs with various structures are calculated to analyse how these tariffs would perform compared to the current increasing tariffs. The alternative tariffs have been designed to compare with average households, so they are not tariffs that can be applied to reality. Due to the tariff structures that are analysed, the evolution of the price, depending on the amount of water consumed, varies significantly. In any case, prices increase in order to discourage excessive consumption. These alternative tariffs are designed to maintain the average price paid for water (the average for all households, which is €2.82/m^3) so that the reaction to the price is minimal. However, households far from the average consumption level would perceive a price change that could modify their consumption. This reaction has not been taken into account in order to simplify the analysis. Therefore, we explain the five designed tariff structures, which can be found in Tables A1., A.2., and A.3. of the Appendix.

First, the linear increasing tariff implies a constant price increase for each cubic metre consumed. Secondly, the logarithmic tariff, depending on the quantity consumed, involves large price increases at the beginning and decreases as consumption increases. Third, the exponential quantity-based tariff involves small price increases for low consumption but very high price increases for high consumption. The fourth tariff design combines the increasing tariffs with the linear increasing tariff discussed above. Thus, the different brackets are increasing, but, in addition, each tranche grows at a higher rate than the previous one, so that with each cubic metre consumed, the price grows, and as the consumer moves through the brackets, the price grows faster and faster. Finally, we have made a tariff that is the opposite of the previous one because although all the brackets imply an increase in price for each cubic metre consumed, the increase is smaller as the consumer moves through the different brackets.

Moreover, these tariffs have been calculated three times, first for the average water consumption and unit price per household, i.e., the tariffs are designed to, based on the average household consumption, maintain the unit price that households present as a whole. Secondly, these tariffs are recalculated according to the water consumption and unit price per person. Finally, we have recalculated the tariffs based on the data for each household type. These tariffs are calculated individually for each household type so that the unit price paid as a whole is maintained but based on the average consumption of each household type. This approach leads to an approximation of the unit price by all households so that those paying a lower price would see an increase in price while those paying a higher price would see a decrease. From all these calculations, we are able to analyse the issues related to alternative tariff structures and the feasibility of their implementation, as well as determine the importance of the household structure in tariff design. However, it should be noted that, as the calculations are made manually to adapt the structures to actual consumption and price, the calculations are not entirely accurate but approximate. These tariffs are, therefore, examples of alternative tariff structures based on regional price and consumption data. Since, in practice, the management scale may differ, any such tariff would have to be recalculated for each situation.

3. Results

3.1. Analysis of the current household water supply tariffs

Before proceeding to the econometric analysis, Table 1 shows the mean values of the key variables by household type. As can be seen, all these variables show a large dispersion depending on the household type, especially in terms of consumption, as larger households have relatively higher consumption. However, considering the number of household members, consumption per person decreases as the size of the household increases. Unit price is the variable with the lowest dispersion, with larger households paying a slightly higher price but also having a significantly higher income. The reduced price dispersion means that higher-income households require a smaller proportion of their income to meet this expense, although their higher total consumption moderates the differences in the weight of the water in their income. In summary, the dispersion of these variables by household type shows the need for a more in-depth analysis of these aspects to design an efficient tariff.

As a result of applying the methodology explained above to the available data, we obtain Table 2, which contains four different estimations. Except for the case of consumption, where the size of the municipality and the high population density significantly influence household water consumption, both the variables of municipality size and population density are not relevant in explaining the dependent variables. On the other hand, household income, as well as household water consumption and price, show apparent effects. Income is significant in explaining the unit price and, of course, the weight of the water bill on household income. Water consumption clearly shows that the

Table 1
Average values of the variables in the analysis by household type.

Household type	Consumption per household (m^3)	Consumption per person (m^3)	Household members	Unit Price (€)	Monthly income (€)	Invoice weight on household income (%)
One adult without children	91.92	91.92	1	1.71	1354.32	1.09
Two adults without children	120.28	60.14	2	1.71	2032.86	0.91
Other households without children	109.68	44.38	2.57	1.71	1511.77	1.31
One adult with at least one child	131.20	41.39	3.25	1.72	2741.51	0.86
Two adults with one child	123.01	41.00	3	1.72	2423.90	0.80
Two adults with two children	137.27	34.32	4	1.74	2777.01	0.81
Two adults with three or more children	137.28	26.44	5.28	1.87	2106.47	1.31
Other households with children	144.97	31.96	4.66	1.79	2603.11	0.87

higher the consumption, the lower the unit price. This effect is due to the fixed price component of the water bill so that when the quantity consumed increases, the unit price decreases as the fixed payment is divided into a larger quantity of water. The unit price shows two distinct effects. Firstly, price negatively impacts consumption due to consumer reaction. Secondly, a higher unit price is naturally related to a higher weight of the bill on household income. Finally, the household type variables show substantial differences in consumption and price between household types, although the differences in weight are not apparent. Of course, total water consumption is higher as there are more members in the household, but the results for consumption per person show the opposite effect, i.e., the more people in a household, the lower the consumption per person. However, the unit price is higher as there are more members in the household, which is because current tariffs do not consider the household structure when calculating payments. Therefore, although consumption per person is lower in larger households, the unit price they pay is higher, so alternative tariff structures should be explored to induce efficiency and equity in water management.

3.2. *Alternative tariff structures based on the average consumption of all households*

The first tariff design applies to all households equally based on their total consumption. In other words, this tariff does not consider the household's composition, so the appropriateness of alternative tariff structures can be analysed. As discussed in the data section, five different tariffs have been designed, which can be found in Table A.1. in the Appendix and their results in Tables A.4., A.5. and A.6. in the Appendix.

The alternative tariffs have varied effects depending on their structure and household structure. Thus, all tariffs, as they are designed based on average consumption per household, would lead to significant savings for smaller households, accentuating the current situation of higher unit prices in larger households. However, this effect varies depending on the tariff structure. Except for the logarithmic tariff, all tariffs imply savings for single-person households and childless households other than single-person and two-person households. For large households, these tariffs imply an increase in the payments made. However, the logarithmic tariff means lower payments for all household types. The exponential tariff is characterised by a higher increase in the price of water for the most populated households. All other tariffs are intermediate with respect to the two previously described. However, they maintain that component of inequality that favours smaller households and disadvantages larger households by not taking into account the structure of the household. Therefore, in the same way, that a simple price increase would not be efficient without considering the household's structure, these alternative tariff designs would not solve the current problems. It is, therefore, necessary to test other possibilities, such as considering the household structure or, more simply, the number of household members.

3.3. *Alternative tariff structures based on the average consumption per person*

The second type of tariff is designed in the same way as the previous group, but in this case, the consumption used as a reference is the average consumption per person to avoid larger households paying a higher unit price. The tariffs designed can be found in Table A2 of the Appendix and their results in Tables A.7., A.8. and A.9. of the Appendix.

In this case, the effect of the alternative tariffs has been the opposite compared to the previous tariffs. This time, while most household structures enjoy savings, the one-person household sees a large price increase. By considering the number of household members and not the household structure, these tariffs are generating the opposite effect to the current one, as they favour the most populated households. It is not only the number of people living in a household that matters, but also their characteristics and the household structure, as consumption per person varies according to the household type. In other words, as the relationship between the number of household members and water consumption is not linear, these tariffs are inefficient as they do not take this into account. Therefore, applying these tariff structures based on the number of household members would lead to inequalities opposite to those that occur at present, with the high per capita consumption of smaller households being penalised excessively.

3.4. *Alternative tariff structures based on the average consumption of each household type*

The designed tariffs are applied on a household basis to enhance their efficiency. In practice, such tariffs can be very complicated to implement, requiring the bill collector to have detailed information on households. However, the analysis may be helpful for tariff modifications. These tariffs can be found in Table A.3. of the Appendix and their results in Tables A.10, A.11. and A.12 of the Appendix.

A more balanced effect can be observed in this case than in the previous cases. This result is logical, as these tariffs deal very specifically with the household structure each would apply. As seen in Table 2, we can observe how larger households paid a relatively higher price than smaller ones. Thus, small households were not penalised for their high consumption per person, and large households were forced to pay a higher unit price due to their rapid progress through the consumption brackets. These alternative tariffs would end this situation, as they would be designed specifically for each household structure and would allow the tariff to be tightened or softened for specific types of consumers. Thus, these tariffs, calculated based on the average consumption per household for each household type and the average price for society as a whole, imply a slight price increase for the least populated households and a small reduction for the most populated ones. With these tariffs, the changes are minor compared to previous tariff types as they

Table 2
Econometric estimations of Eq. (1).

	Water Consumption per household	Water Consumption per person	Unit Price	Weight of the invoice
Town of between 10,000 and 20,000 Inhabitants	0.284 (0.049)***	0.299 (0.050)***	0.061 (0.042)	−0.005 (0.064)
Town of between 20,000 and 50,000 Inhabitants	0.393 (0.069)***	0.416 (0.070)***	−0.181 (0.051) ***	0.126 (0.082)
Town of between 50,000 and 100,000 Inhabitants	0.356 (0.083)***	0.383 (0.083)***	−0.047 (0.053)	0.221 (0.098) **
Town of more than 100,000	0.259 (0.071)***	0.286 (0.072)***	−0.063 (0.052)	0.006 (0.080)
Average Population Density	−0.075 (0.046)	−0.063 (0.046)	−0.053 (0.030) *	−0.004 (0.054)
High Population Density	0.283 (0.068)***	0.299 (0.069)***	0.044 (0.051)	0.092 (0.075)
Income of the Household (€/year)	0.099 (0.030)***	0.166 (0.057)***	0.023 (0.007) ***	−0.377 (0.020) ***
Water Consumption (m^3)	– –	– –	−0.378 (0.024) ***	0.006 (0.000) ***
Unit Price (€)	−0.701 (0.062)***	−0.747 (0.058)***	– –	0.499 (0.034) ***
Unit price*Income	−0.000 (0.000)	−0.022 (0.031)	– –	– –
Two adults without children	0.197 (0.033)***	−0.417 (0.032)***	0.068 (0.025) ***	−0.071 (0.035) **
Other households without children	0.277 (0.041)***	−0.748 (0.042)***	0.094 (0.033) ***	0.075 (0.053)
One adult with at least one child	0.127 (0.076)*	−0.682 (0.079)***	0.014 (0.052)	0.174 (0.151)
Two adults with one child	0.209 (0.045)***	−0.762 (0.044)***	0.072 (0.029) **	−0.054 (0.061)
Two adults with two children	0.328 (0.046)***	−0.898 (0.045)***	0.137 (0.031) ***	−0.002 (0.046)
Two adults with three or more children	0.444 (0.084)***	−1.049 (0.088)***	0.253 (0.053) ***	0.158 (0.127)
Other households with children	0.429 (0.050)***	−0.928 (0.051)***	0.164 (0.039) ***	−0.084 (0.044)*
Constant	4.349 (0.085)***	4.241 (0.090)***	2.172 (0.103) ***	0.150 (0.113)
R^2	0.41	0.59	0.43	0.52
N	1612	1612	1612	1612

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

are designed based on the average of households of the same type, so there are no imbalances resulting from applying the same tariff to a large and varied group of households.

In summary, these results have clearly shown that the tariffs applied to a too diverse set of consumers are not efficient. However, the great need for information to use this type of tariff makes it very difficult to design a price that adequately fulfils its objectives. The tariffs that do not consider the household structure, no matter their structure, are inefficient because of their application to a broad set of consumers.

4. Discussion

The analysis of tariff alternatives based on the average consumption and prices observed among households in the Region of Valencia has revealed the difficulty of correcting the current tariff imbalances. Some papers have highlighted the significant differences between regions in terms of tariffs and taxes on water services (García-López and Montano, 2020; García-Valiñas and Arbués Gracia, 2020; García-Valiñas and Arbués, 2021). To these differences, we must add that, by not considering the household structure in tariffs, we are generating another imbalance between payments for water services between different household typologies. Therefore, analyses that can generate information on how to make changes to address these imbalances are helpful.

However, territorial imbalances are challenging to solve, as often the competences for water services are held by local or regional authorities. Therefore, a national regulation would be required to address this issue, which is very complicated, as the regulation should induce balance in the system while allowing each region to adapt the payments for water services to its specific situation. Regarding tariff and household structure, the current structure of increasing brackets has proven to be inefficient in inducing equity between different household types. In order to address this issue, it has been analysed how other types of tariffs would affect households. Unfortunately, none of the structures analysed has proven to be efficient, as the problem of inequity remains as the household structure is not considered. The effects vary depending on the type of tariff, but the main problem remains. A tariff that seeks to penalise households with few members without considering the household structure will excessively affect households with more members. Therefore, the problem is not only the structure of the tariff but the fact of not considering the household type.

One of the alternatives that have been proposed to solve this problem is to take into account the number of household members. This task can be complicated, as it involves an effort to get this information to the entity responsible for making the payments. In any case, the analysis carried out when designing tariffs based on average consumption per person affirms that it would not be efficient to modify the tariff in this way either. The consumption pattern does not evolve linearly, i.e., as the number of household members increases, consumption evolves differently, and the tariff cannot capture this effect. Thus, the consumption per person of the most populated households is much lower than that of households with one or two members. This difference in consumption patterns should be studied further, but in general, there are indications that it is easier to save water as the number of household members increases. Therefore, this tariff would penalise small households not necessarily for over-consumption but for something entirely out of their control. In short, pricing based on the number of household members has proven to be counterproductive, as it is still associated with inequity, albeit in this case in reverse, and would entail a high cost due to having to collect information on households.

Given the problems associated with the tariff structures studied, it becomes necessary to analyse other types of tariffs. In particular, tariffs designed for each household type, as they are adapted to the characteristics of each household, have made it possible to induce fairness in payments. Specifically, regardless of its structure, this type of tariff allows the consumption pattern of each household type to be taken into account so that payments are adapted, and no household is penalised as a result of the tariff structure. Thus, the results have shown that these tariffs would allow balancing payments for water services. However, household information would be needed to apply the tariffs, which could be accomplished through public tools such as the municipal register or by leaving the responsibility to provide information to consumers. This second option could be very complicated, but some sanctions could be established in case of failure to provide the information. For example, households that do not contribute could be charged the highest price, thus providing an incentive to collaborate. In any case, the latter type of tariff is the only alternative that has proven to be efficient after the problems related to the previous ones. Therefore, the question is not simply whether the current tariffs are structurally adequate, as other structures also present the same problems. In other words, the problem lies in the difficulty of obtaining the necessary information for the types of tariffs that have proven to be efficient and whether it is cost-effective to make such an effort.

5. Conclusions

This work has analysed the current tariff structure to determine the problems that should be addressed. To this end, alternative tariff structures have been studied to induce equity in payments for water services. For this purpose, data from the Household Budget Survey carried out by the Spanish National Statistics Institute have been used.

The analysis has begun by confirming with recent information how the increasing-block rate used to raise revenue for the water supply service cannot do so equitably between different household types. Thus, alternative tariffs have been designed to test the feasibility of improving the efficiency of water supply payments. However, none of the tariffs studied effectively solve the current problems. As a result, tariffs have been redesigned to take into account the size of the household. However, because the consumption pattern is different according to the structure of the household, these types of tariffs hit smaller households too hard. Tariffs designed based on capita consumption produce the opposite effect to what currently exists.

Neither alternative tariff structures nor taking into account the number of household members are effective solutions to the problems of current tariffs. In other words, other household characteristics should be considered if we want to design efficient and equitable tariffs. Thus, the tariffs have been redesigned based on the characteristics of each of the eight household types analysed. In this case, the tariffs can induce equity in the system, as they allow the payments of each household type to be adapted to their characteristics. On the other hand, the difficulty associated with such a modification should not be overlooked, as the cost can be very high. This issue may make this alternative unfeasible, as the costs may outweigh the benefits. These results are of great use to the public planner, as it eliminates the need to design alternative tariff structures, as the problem lies in valuing household composition. In other words, this research conveys to public planners that the way to improve water tariffs is to adapt them to the characteristics of households, for which public entities will have to assess whether they have the resources to do so and whether the benefits obtained outweigh the costs that would be incurred. In any case, the analysis has provided relevant information for the modification of tariffs, which is particularly important in countries such as Spain, where there is no equity in payments for water services between regions or between household types and where full cost recovery is not achieved. In other words, Spain is in a complicated situation, as it needs additional revenues, but simple measures to implement, such as a price increase or alternative tariff structures, are inefficient, and other alternatives are costly to implement and may compromise the benefits of the policy.

Finally, some limitations of this work should be noted. Firstly, due to the available data, it is impossible to analyse tariffs at the local level, which is desirable since local governments are in charge of tariffs. Secondly, since data are annual, it is impossible to study consumption over the different seasons of the year. Finally, the tariffs that have been designed are based on consumption and price averages so that their performance with observations that are far from the averages would vary. Even with these limitations, the analysis is useful in confirming current problems and generating information related to their possible solution. The possibility remains open for more precise analysis with city-specific information so that the data are not an aggregate of a wide variety of tariffs with different consumption brackets and amounts.

Author contributions

Marcos García-López: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Original Draft, Visualization, Funding acquisition. **Borja Montano:** Conceptualization, Formal analysis, Investigation, Writing - Review & Editing, Supervision, Funding acquisition. **Joaquín Melgarejo:** Conceptualization, Investigation, Writing - Review & Editing, Supervision, Funding acquisition.

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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 data used are available on the website of the Spanish National Statistics Institute. The submitted manuscript includes the link to the data used.

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Appendix

Table A.1
Price per cubic metre of the tariff alternatives for all households based on total consumption.

Tariff type	Cost per cubic metre
Linear increasing	= 0.029Q
Logarithmic	= 0.815LOG(Q)
Exponential	= $0.000367Q^2$
Increasing-block	Up to $30m^3$ 0.0345Q
	From $30m^3$ to $60m^3$ 1.035 + 0.028Q
	From $60m^3$ to $90m^3$ 1.875 + 0.022Q
	From $90m^3$ 2.535 + 0.015Q
Decreasing-block	Up to 30m3 0.025Q
	From $30m^3$ to 60 m^3 0.75 + 0.029Q
	From $60m^3$ to $90m^3$ 1.62 + 0.035Q
	From $90m^3$ 2.67 + 0.04Q

Source: Own elaboration based on INE data.

Table A.2
Price per cubic metre of the tariff alternatives for all households based on consumption per person.

Tariff type	Cost per cubic metre
Linear increasing	= 0.0585Q
Logarithmic	= 1.28LOG(Q)
Exponential	= $0.0015Q^2$
Increasing-block	Up to 20m^3 0.065Q From 20m^3 to 40 m^3 1.3 + 0.055Q From 40m^3 to 60 m^3 2.4 + 0.033Q From 60m^3 3.06 + 0.025Q
Decreasing-block	Up to 20m3 0.05Q From 20m3 to 40 m3 2 + 0.066Q From 40m3 to 60 m3 2.32 + 0.081Q From 60m3 3.94 + 0.1Q

Source: Own elaboration based on INE data.

Table A.3
Price per cubic metre of the tariff alternatives by household type based on household consumption.

Tariff structure / Household type	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children (78m3)	0.0371Q	1.12LOG(Q)	$0.000601Q^2$	Up to 30m^3 0.03Q From 30m^3 to 60 m^3 0.9 + 0.04Q From 60m^3 to 90m^3 2.1 + 0.06Q From 90m^3 3.9 + 0.1Q	Up to 30m^3 0.045Q From 30m^3 to 60 m^3 1.35 + 0.03Q From 60m^3 to 90m^3 2.25 + 0.022Q From 90m^3 2.91 + 0.015Q
Two adults without children (92m3)	0.0285Q	1.04LOG(Q)	$0.000355Q^2$	Up to 30m^3 0.02Q From 30m^3 to 60 m^3 0.6 + 0.03Q From 60m^3 to 90m^3 1.5 + 0.04Q From 90m^3 2.7 + 0.045Q	Up to 30m^3 0.04Q From 30m^3 to 60m^3 1.2 + 0.025Q From 60m^3 to 90m^3 1.95 + 0.014Q From 90m^3 2.37 + 0.01Q
Other households without children (101m3)	0.03105Q	1.065LOG (Q)	$0.000422Q^2$	Up to 30m^3 0.02Q From 30m^3 to 60 m^3 0.6 + 0.032Q From 60m^3 to 90m^3 1.56 + 0.051Q From 90m^3 3.09 + 0.073Q	Up to 30m^3 0.04Q From 30m^3 to 60 m^3 1.2 + 0.03Q From 60m^3 to 90m^3 2.1 + 0.023Q From 90m^3 2.58 + 0.01Q
One adult with at least one child (91m3)	0.0261Q	1.02LOG(Q)	$0.000298Q^2$	Up to 30m^3 0.015Q From 30m^3 to 60 m^3 0.45 + 0.025Q From 60m^3 to 90m^3 1.2 + 0.0335Q From 90m^3 2.205 + 0.04Q	Up to 30m^3 0.035Q From 30m^3 to 60 m^3 1.05 + 0.025Q From 60m^3 to 90m^3 1.8 + 0.017Q From 90m^3 2.31 + 0.01Q
Two adults with one child (96m3)	0.0278Q	1.035LOG (Q)	$0.000338Q^2$	Up to 40m^3 0.02Q From 40m^3 to 80 m^3 0.8 + 0.031Q From 80m^3 to 120m^3 2.04 + 0.05Q From 120m^3 4.04 + 0.06Q	Up to 40m^3 0.034Q From 40m^3 to 80 m^3 1.36 + 0.0245Q From 80m^3 to 120m^3 2.34 + 0.01Q From 120m^3 2.74 + 0.005Q
Two adults with two children (103m3)	0.025Q	1.007LOG (Q)	$0.000273Q^2$	Up to 40m^3 0.02Q From 40m^3 to 80 m^3 0.8 + 0.025Q From 80m^3 to 120m^3 1.8 + 0.038Q From 120m^3 3.32 + 0.05Q	Up to 40m^3 0.03Q From 40m^3 to 80 m^3 1.2 + 0.025Q From 80m^3 to 120m^3 2.2 + 0.011Q From 120m^3 2.64 + 0.005Q
Two adults with three or more children (102m3)	0.025Q	1.007LOG (Q)	$0.000273Q^2$	Up to 40m^3 0.02Q From 40m^3 to 80 m^3 0.8 + 0.025Q From 80m^3 to 120m^3 1.8 + 0.038Q From 120m^3 3.32 + 0.05Q	Up to 40m^3 0.03Q From 40m^3 to 80 m^3 1.2 + 0.025Q From 80m^3 to 120m^3 2.2 + 0.011Q From 120m^3 2.64 + 0.005Q
Other households with children (109m3)	0.0236Q	0.993LOG (Q)	$0.000244Q^2$	Up to 40m3 0.018Q From 40m3 to 80 m3 0.72 + 0.024Q From 80m3 to 120m3 1.68 + 0.035Q From 120m3 3.08 + 0.045Q	Up to 40m^3 0.03Q From 40m^3 to 80 m^3 1.2 + 0.023Q From 80m^3 to 120m^3 2.14 + 0.01Q From 120m^3 2.54 + 0.005Q

Source: Own elaboration based on INE data.

Table A.4
Unit price of the tariff alternatives for all households based on total consumption.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	1.35	1.26	1.05	1.28	1.43
Two adults without children	1.76	1.35	1.79	1.76	1.75
Other households without children	1.60	1.32	1.49	1.58	1.64
One adult with at least one child	1.92	1.38	2.13	1.96	1.86
Two adults with one child	1.80	1.36	1.87	1.81	1.78
Two adults with two children	2.00	1.40	2.33	2.07	1.92
Two adults with three or more children	2.01	1.40	2.33	2.07	1.92
Other households with children	2.12	1.42	2.60	2.21	1.99

Source: Own elaboration based on INE data.

Table A.5
Weight of the water bill in the income of the tariff alternatives for all households according to total consumption.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	0.76	0.71	0.59	0.81	0.72
Two adults without children	0.87	0.67	0.88	0.86	0.87
Other households without children	0.97	0.80	0.90	0.99	0.95
One adult with at least one child	0.76	0.55	0.85	0.74	0.78
Two adults with one child	0.76	0.57	0.79	0.75	0.77
Two adults with two children	0.83	0.58	0.96	0.79	0.85
Two adults with three or more children	1.09	0.76	1.27	1.04	1.13
Other households with children	0.98	0.66	1.21	0.93	1.03

Source: Own elaboration based on INE data.

Table A.6
Variation of the weight of the bill on household income of the tariff alternatives for all households based on total consumption.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	−0.21	−0.26	−0.37	−0.16	−0.24
Two adults without children	0.02	−0.18	0.04	0.02	0.03
Other households without children	−0.06	−0.23	−0.13	−0.04	−0.08
One adult with at least one child	0.08	−0.14	0.16	0.05	0.09
Two adults with one child	0.03	−0.15	0.06	0.02	0.04
Two adults with two children	0.11	−0.14	0.24	0.08	0.14
Two adults with three or more children	0.07	−0.26	0.25	0.03	0.11
Other households with children	0.15	−0.17	0.38	0.10	0.20

Source: Own elaboration based on INE data.

Table A.7
Unit price of the tariff alternatives for all households based on consumption per person.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	2.66	1.95	4.16	2.32	2.32
Two adults without children	1.74	1.71	1.82	1.73	1.73
Other households without children	1.32	1.60	0.99	1.40	1.40
One adult with at least one child	1.28	1.55	1.18	1.32	1.32
Two adults with one child	1.17	1.50	0.81	1.25	1.25
Two adults with two children	0.97	1.40	0.56	1.06	1.06
Two adults with three or more children	0.76	1.27	0.34	0.83	0.83
Other households with children	0.93	1.39	0.50	1.01	1.01

Source: Own elaboration based on INE data.

Table A.8
Weight of the water bill on the income of the tariff alternatives for all households based on consumption per person.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	1.50	1.10	2.35	1.31	1.72
Two adults without children	0.86	0.84	0.90	0.85	0.87
Other households without children	0.80	0.97	0.60	0.84	0.75
One adult with at least one child	0.51	0.62	0.47	0.53	0.49
Two adults with one child	0.49	0.63	0.34	0.53	0.46
Two adults with two children	0.40	0.58	0.23	0.43	0.36
Two adults with three or more children	0.41	0.69	0.18	0.45	0.36
Other households with children	0.43	0.65	0.23	0.47	0.38

Source: Own elaboration based on INE data.

Table A.9
Variation of the weight of the bill on household income of the tariff alternatives for all households based on consumption per person.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	0.54	0.13	1.38	0.34	0.75
Two adults without children	0.01	0.00	0.06	0.01	0.02
Other households without children	−0.23	−0.06	−0.43	−0.19	−0.28
One adult with at least one child	−0.18	−0.07	−0.22	−0.16	−0.20
Two adults with one child	−0.23	−0.10	−0.39	−0.20	−0.27
Two adults with two children	−0.31	−0.14	−0.48	−0.28	−0.35
Two adults with three or more children	−0.61	−0.33	−0.83	−0.56	−0.66
Other households with children	−0.40	−0.18	−0.60	−0.36	−0.45

Source: Own elaboration based on INE data.

Table A.10
Unit price of the tariff alternatives by household type based on household consumption.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	1.72	1.73	1.72	1.73	1.72
Two adults without children	1.73	1.72	1.73	1.73	1.73
Other households without children	1.72	1.72	1.72	1.72	1.72
One adult with at least one child	1.73	1.73	1.73	1.73	1.73
Two adults with one child	1.72	1.73	1.73	1.73	1.73
Two adults with two children	1.73	1.73	1.73	1.72	1.73
Two adults with three or more children	1.73	1.73	1.73	1.72	1.73
Other households with children	1.72	1.73	1.73	1.73	1.73

Source: Own elaboration based on INE data.

Table A.11
Weight of the water bill on the income of the tariff alternatives by household type based on household consumption.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	0.97	0.98	0.97	0.98	0.97
Two adults without children	0.85	0.85	0.85	0.85	0.85
Other households without children	1.04	1.04	1.04	1.04	1.04
One adult with at least one child	0.69	0.69	0.69	0.69	0.69
Two adults with one child	0.73	0.73	0.73	0.73	0.73
Two adults with two children	0.71	0.71	0.71	0.71	0.71
Two adults with three or more children	0.94	0.94	0.94	0.94	0.94
Other households with children	0.80	0.80	0.80	0.80	0.80

Source: Own elaboration based on INE data.

Table A.12
Variation of the weight of the bill on household income of the tariff alternatives for all households based on household consumption by household type.

	Linear increasing	Logarithmic	Exponential	Increasing-block	Decreasing-blocks
One adult without children	0.01	0.01	0.01	0.01	0.01
Two adults without children	0.01	0.01	0.01	0.01	0.01
Other households without children	0.01	0.01	0.01	0.01	0.01
One adult with at least one child	0.00	0.00	0.00	0.00	0.00
Two adults with one child	0.00	0.00	0.00	0.00	0.00
Two adults with two children	0.00	0.00	0.00	−0.01	0.00
Two adults with three or more children	−0.08	−0.08	−0.07	−0.08	−0.08
Other households with children	−0.03	−0.03	−0.03	−0.03	−0.03

Source: Own elaboration based on INE data.

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