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Article

Residential Demand for Water in a Nature Reserve of Mexico: Evidence of Effects of Perceived Price

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Abstract: The purpose of this paper is to provide empirical evidence to water policy-makers and the evaluation of the application of economic instruments such as price and other factors affecting demand, they contribute to improved decision-making around water management in the Biosphere Reserve El Vizcaino, Mexico. It was estimated a dynamic function with average price specification and other price perception specification. The findings show that consumers react to average price perceived and not the marginal price; long-run price elasticity is higher than short-run and both elasticities are inelastic. Elasticities inelastic with rising prices generate high incomes to improve water planning, supply quality and expand service coverage. The results suggest that the level of knowledge of users on the price is key to take into account restructuring rates in a scenario where the consumer has asymmetric information and themselves achieve goals of economic efficiency, social equity and environmental sustainability.

Keywords: lagged consumption; dynamic function; water management; average price; marginal price

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1. Introduction

The literature has indicated that the price system is complement with the legal environmental aspects and is one of the most important instruments management to additional gain economic efficiency, improve the equity and maintain the sustainability of hydrological resources [1-3]. The effect of pricing policy is incentives to change the behavior pattern of water consumption of individuals for the responsible use and there by control water demand, mainly in regions where water resources are limited; also revenues can generate greater increased financial resources for management and the agencies should be improve water supply planning. Following like objective, reducing of sectors of the population without access to water and guarantee it with the quality that international standards require using technologies that use water efficiently and incorporate into the catering process recycling and reuse of water. Similarly an increase in prices has the effect of water reallocation between sectors (irrigation to domestic and industrial).

Acoording to Rogers *et al.* [1] the main functions of tariffs must meet the following objectives: 1) maximize the efficient allocation of resources; 2) water users should perceive the tariff as fair ; 3) rates should be equitable between customer classes ; 4) must generate sufficient income ; 5) providing the stability of net income ; 6) the public should understand the process of setting tariffs ; 7) promote resource conservation; 8) the rate-setting scheme should avoid shocks in rates ; 9) it is easily implemented ; 10) the water should be accessible ; 11) the rates should be with future vision ; 12) The rates structure should try to reduce administrative costs ; 13) should include environmental costs ;

14) should be no conflict with other government policies ; 15) should reflect the characteristics of supply and water quality, reliability and frequency of supply; 16) should vary depending measurability and consumption ; 17) structures more sophisticated rates may also take into account the daily peaks and seasonal variations in water demand .

In this sense, the measuring of the potential impact of pricing policy on management of water demand it has motivated the growth of methods to estimate more precisely the price elasticity of demand and income [4-5]. The specifications most used in the development of the research are the marginal price, the average price and the combination of these two. However, in the literature of studies water demand exist controversy about which option price is more suitable as used to obtain more precise estimates of elasticities when users pay their water consumption under a pricing structure block. The center of the debate is based on asymmetric information consumer price block. The middle of which they have to find out the total amount to pay for what you use is the receipt of payment (people not know the price structure block, therefore, they not know the marginal price). Users adjust their consumption behavior to variations in average prices, because it is too expensive for them to learn marginal prices and therefore, do not have sufficient incentives to invest in time and learn about them [6-7].

Therefore, it is difficult to contrast the hypothesis of residential water consumers who have complete knowledge about the tariff scheme [8-9]. Arbués *et al*. [4], Worthington & Hoffman [5] in a review of empirical studies of water demand, show that in most cases there are no significant differences in the results of the elasticities derived from these two types of specifications and the results are not conclusive about which alternative price is better use. Although studies reveal price elasticities of demand inelastic, the long-term elasticity is greater than the short-term for considerable time, producing substantial effects on consumer reaction. Under tiered pricing increasing non-linear, the elasticities are higher compared with decreasing blocks and uniform prices, as the first structure tends to send stronger signals to reduce water consumption [10-11] and is the rate chosen by developing countries [12].

A great difficulty that researchers to do their empirical work is the availability of information where much is added and hardly micro level data is accessible. Given the availability of information and given the benefits that can be obtain with some price methodologies, the goal in this paper is to estimate a dynamic function that incorporates the average price, the methodology of Shin [13] seeking to verify the hypothesis of consumer reaction to perceived changes in prices and not actual prices.

2. Materials and Methods

2.1. Study Area

The localization limits of the Vizcaino Reserve are: from the West side starts from the 28th parallel, extending from the Laguna Guerrero Negro to the estuary El Datil , on the East side extends from the 28th parallel to Santa Rosalia, and from this last point through the southeast through the transpeninsular highway , through the Laguna San Ignacio and Barra of San Juan (Figure 1).

The Reserve is one of the most largest in Latin America with an area of 2,546,790.25 hectares. It is characterized by an arid region with dry climate and low rainfall [14]. By to weather and geological conditions the population uses the water by pumping from aquifers.

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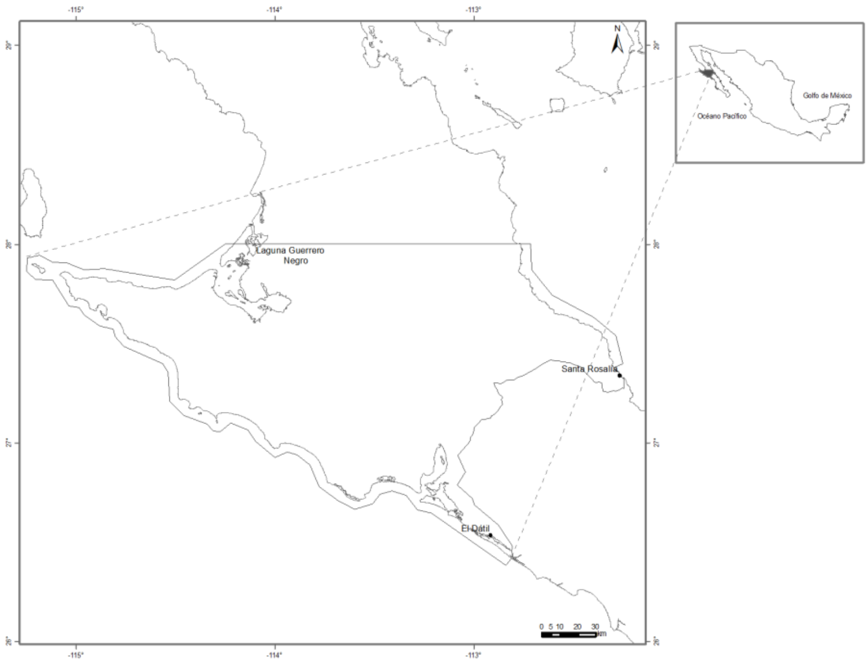

Figure 1. Area of Biosphere Vizcaino Reserve

2.2 Specifying of water demand dynamics

The relations of dynamic character by nature in a model, can be studied by incorporating the lagged dependent variable among the regressors, known as autoregressive model. The equation is a bilogarithmic form,

$$\ln w_{it} = \delta \ln w_{i,t-1} + \ln z'_{it} \beta + \mu_i + v_{it} \tag{1}$$

where $\ln w_{it}$ is the natural logarithm of the average water consumption of the community i-th time t, $\ln w_{i,t-1}$ is the natural logarithm of consumption lagged one month, z a matrix of size (n× m) containing m independent variables (price, income, maximum temperature and total monthly rainfall), β is a vector of size parameters (m × 1). μ_i constitutes the discrepancies among consumers that correspond to each community, generally not designed by the researcher and is taken into account as a fixed effect. The stochastic component v_{it} represents the distance between the estimated consumption and consumption observed frequently not inferred by the researcher.

The lag of the dependent variable is because current consumption depends heavily on past consumption habits of water consumption, because users do not change them for psychological, technological or institutional reasons; the current consumption depends on the previous month by household equipment such as showers, toilets, washing machines, etc. The frequency of use of this type of goods change in the short term and gradually change its characteristics by the replacement of those most wáter saver (long term). People do not buy household appliances that consume less water than the market instantly sends the signals by the high cost of replacing them, related to limiting their budget constraint.

These types of factors provokes users a no immediate reaction to changes in prices and is slow adjusting their consumption. In this sense, displacements are expected in greater demand curve in the long run. According to the above, the approach is desirable to formulate through a partial adjustment model because water is a basic necessity [15]. Therefore, highly relevant existing inertia in consumption, reflecting them by incorporating the lagged dependent variable among the regressors. The average price methodology was selected because users lack information on the pricing structure block, let alone the marginal price. The bill received after the consumption made, and for this reason, it probable that the user takes into account the bill last month to decide on water

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consumption. Under these conditions the consumer pays their bills in an environment of asymmetric information.

In addition, much of the existing studies do not provide inertia in consumption resulting from their habits and not instantaneous response of individuals to variations in rates. In this sense, the actual consumption adjusts quickly (during the same period) to the desired level. This type of approach may not be realistic according to the arguments explained in the partial adjustment model. Not consider these aspects could generate partial and inconsistent estimates. Additionally, the methodology Shin [13] is used to contrast his hypothesis is to argue that consumers do not adjust their consumption to variations in real prices, they adjust to changes in perceived prices. There are several reasons why it is too expensive for the consumer to determine the actual rate paid by drinking water: 1) It is difficult for consumers to know the difference between the average price and the marginal and its impacts on consumption , insomuch that is unaware of the pricing structure block ; 2) If you succeed know the price structure in blocks, it would be difficult to respond to changes in prices and only adjust its consumption billed following receipt of payment ; 3) It is very unlikely that the consumer does not discern water prices of other components derived from the invoice payment and sewer service.

In summary, the methodological approach of Shin [13] is that consumers consider the marginal costs and marginal benefits, to calculate a marginal price without solid foundations, reacting to variations in perceived prices and not to an estimated amount that reflects actual prices. Depending on the weight gets three results response of consumption to prices: 1) If the marginal benefit is less than the marginal cost , the consumer will not respond to the marginal price and determine their consumption on other price information ; 2) If the marginal expected benefit is greater than the marginal cost, the consumer will likely determine the actual marginal real price and the price received equal the marginal price: 3) if the price structure equals the marginal cost, the consumer will stop searching information and the price received range from the marginal price and the average price.

According to Shin [13] the perceived price is formulated as follows,

$$P^{*} = MP(AP/MP)^{k} \tag{2}$$

where MP is the marginal price, AP the average price and a parameter k of price perception. The ratio between AP and MP captures the effect of the difference variable on the perception of price. Its expected that the parameter k is not negative. The possible results are: 1) When $k=0$, the consumer reacts to changes in MP ; 2) When $k=1$, the consumer reacts to AP ; 3) Assuming a price structure with increasing block (the rate is progressive) when, P^{*} varies between AP y MP , we get a result $0<k<1$. When $k>1$, $P^{*}<AP<MP$ and when $k<0$, $P^{*}>AP>MP$.

The econometric specification is expressed as follows,

$$\begin{aligned} \ln w_i &= \beta_0 + \alpha \ln PMP_{it} + \beta \ln z_{it}' + \mu_i + v_{it} \\ &= \beta_0 + \alpha[(1-k)\ln MP + k \ln AP] + \beta \ln z_{it}' + \mu_i + v_{it} \\ &= \beta_0 + \beta_1 \ln MP + \beta_2 \ln(AP/MP) + \beta \ln z_{it}' + \mu_i + v_{it} \end{aligned} \tag{3}$$

where $\beta_1 = \alpha(1-k)$, $\beta_2 = \alpha k$, being $k = \beta_2/\beta_1$. z is a matrix of size (n × m) containing m independent variables (income , maximum temperature and total monthly precipitation), β its a parameter vector of size (m × 1).

2.3 Method of estimating water demand dynamics

The dynamic panel with fixed effects is the econometric strategy used to estimate the demand function includes water as a control variable past consumption,

$$y_{it} = \delta y_{i,t-1} + x'_{it}\beta + u_{it} \qquad i=1,\dots,N; t=1,\dots,T \tag{4}$$

con $u_{it} = \mu_i + v_{it}$

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following the approach of Baltagi [16] μ_i is fixed, constant for each individual and $v_{it} \sim IID(0,\sigma_v^2)$ [1].

The model, also assumes that the explanatory variables are uncorrelated with the idiosyncratic error, but may be correlated with the individual effects. However, the presence of the lagged dependent variable in the model causes problems of endogeneity by correlation with the error term [16]. On the other hand, Kiviet [17] suggested an alternative for an intra - group dynamic panel estimator suitable for finite sample corrected. The correction of intra- group flaw estimator is known as the method of least squares corrected binary variables (LSDVC).

In his studies of Monte Carlo, Judson and Owen [18] showed evidence when the period is 30, the flaw of the estimator of fixed effects is considerable. These authors recommend using the estimator LSDVC when the lapse is ≤ 10 and Anderson & Cheng estimator [19] when its length is remarkable. There are other alternatives to correct the problem of endogeneity such as Instrumental Variables estimators (IV) and the Generalized Method of Moments (GMM). However, the latter are designed to $N \rightarrow \infty$ y T fixed, that is, are consistent for a number of large transverse units (N), although the length of the series of time is short. The estimator of Arellano & Bond [20] in small samples has a significant downward bias. This is because one of the disadvantages possessed in the type of IV estimators as AH and GMM as AB and BB is their asymptotic properties depend on that N is large, characteristic of micro panel data.

Recently, Bruno [21] developed a method for obtaining the LSDVC estimator for unbalanced panels. In this method is corrected the flaw from a consistent estimator as AH , AB and BB (Blundell - Bond) where the three alternatives to initialize the flaw correction are asymptotically equivalent. In our case T is relatively large, scilicet $T \rightarrow \infty$ y N few or N is fixed. Cermeño [22] based on his empirical study showed that LSDV estimator bias is lower compared to the estimates considered small T.

2.4. Description of the database

The 2010-2014 period was considered to feed data to the variables of the econometric model and includes seven communities: San Ignacio, Bahia Tortugas, Bahia Asuncion, Villa Alberto Alvarado, Guerrero Negro, Mulege and Santa Rosalia. The description of each is shown in Table 1.

[1] I.I.D. It means that errors are independent and identically distributed.

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Table 1. Description of variables used in the regression analysis

Variable	Description	Source
w	Symbolizes water consumption average per capita residential use. The variable is measured in cubic meters (m^3).	System Operator Agency Water Supply and Sewerage (OOMSAPA).
AP	Average price and is obtained by dividing the water bill paid by the consumer living housing and volume of water consumed. Additionally, the measurement of price was deflated using the National Consumer Price Index (NCPI) , base 2010=100, obtained from the Bank of Mexico (BM).	System Operator Agency Water Supply and Sewerage (OOMSAPA).
PM	Marginal price represents that the consumer must pay, according to the tariff structure for final consumption units associated with the average amount . The price was deflated using the CPI , base 2010=100	System Operator Agency Water Supply and Sewerage (OOMSAPA).
Income	Is defined as the average daily wage quote by state of the Mexican Social Security Institute (IMSS). In the regression analysis it is used as a *proxy* for income, representing an indicator of household income. For purposes of inclusion in the dynamic equations, we calculated monthly. This variable was deflated with CPI base 2010=100 and weighted with the working population .	National Commission for Minimum Wage in the State of Baja California Sur.
t	Monthly maximum temperatura, is measured in degrees Celsius (° C)	National Water Commission (CONAGUA).
p	Is the total monthly precipitation , measured in millimeters (mm).	National Water Commission (CONAGUA).

Table 2 shows the descriptive statistics used in the econometric specifications.

Table 2. Descriptive statistics of the selected variables regression analysis

Variable	Mean	Standar Devation	Minimun	Maximun
Natural logarithm of water consumption	3.08	0.39	1.27	3.92
Natural logarithm of the average price	1.59	0.37	1.22	3.22
Natural logarithm of income	8.44	0.04	8.33	8.5
Natural logarithm temperature	3.48	0.18	2.89	3.78
Precipitation	9.5	25.15	0	218
Natural logarithm of the marginal price	1.49	0.19	1.12	2.88

3. Results and Discussion

The first step that precedes the econometric analysis of demand functions, is the analysis of each of the series represented in the variables. For this unit root tests were performed on data environment panel, proposed by: 1)Breitung [23]; 2)Levin *et al.* [24]; 3)Harris &Tzavalis [25]; 4) Im & Yongcheol [26], known as IPS and; 5)Fisher tests [27] type known as the Dickey-Fuller (ADF) and Phillips-Perron (PP). The results in Table 3 show that it is not necessary to apply cointegration vectors and provide support for working with stationary methods, since it rejects the null hypothesis of non stationarity to common levels of significance.

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Table 3. Results of unit root tests of the variables of the dynamic function

Test		Natural logarithm of water consumption	Natural logarithm of the average price	Natural logarithm of income	Natural logarithm temperature	Natural logarithm of the marginal price	Precipitation
Levin, Lin & Chu t stat₁	No trend	-3.5058*	-2.9591*	-4.7032*	-3.3096*	-5.3825*	-14.8757*
	With trend	-3.7844*	-3.6753*	-4.5454*	-2.9802*	-7.1843*	-16.4279*
Breitung t-stat₁	No trend	-2.016**	0.8364	-2.8989*	-3.8967*	-3.8093*	-11.1172*
	With trend	-2.9742*	-1.7696**	-1.6902**	-3.1495*	-1.5693	-11.1841*
Harris-Tzavalis ₁	No trend	-12.4917*	-9.9615*	-39.8499*	-14.5436*	-29.5214*	-39.8661*
	With trend	-8.4543*	-8.6226*	-30.2714*	-7.3701*	-24.2629*	-24.5517*
Im, Pesaran and Shin W-stat₂	No trend	-4.7914*	-5.1862*	-6.9979*	-9.5987*	-7.1840*	-13.172*
	With trend	-4.9233*	-3.7272*	-13.1415*	-8.9286*	-9.8964*	-13.7871*
ADF - Fisher Chi-square₂	No trend	61.273*	24.9921**	76.8509*	117.714*	87.2638*	170.723*
	With trend	55.8855*	36.2216*	158.721*	98.8576*	112.370*	161.536*
PP - Fisher Chi-square₂	No trend	61.0525*	42.2184*	209.668*	81.1587*	83.0181*	183.702*
	With trend	54.2991*	59.9753*	234.038*	57.8068*	105.175*	156.455*

Note: * the null hypothesis is rejected at nonstationarity 1%; ** the null hypothesis is rejected at nonstationarity 5%; 1 represent a common unit root process; 2 represent an individual unit root process.

Starting with the dynamic panel, the regression results of Table 3 show the variation of the demand for residential water attributed to the independent variables considered in the analysis. A significance level of 1 % , with a value between $0 < w_{i,t-1} < 1$, resulted average consumption lagging. The speed adjustment is obtained by subtracting 1 to 0.62 (coefficient), the difference being 0.38. His interpretation indicates that the gap of 38% between actual and desired demand for water is shortened by one month. With respect to the result of the price elasticity of demand it obtained the expected sign and inelastic demand, as economic theory suggests an inverse relationship between quantity demanded and price. It indicates that the user response to the percentage change in price, the percentage change in quantity demanded is less than the percentage change in price.

The short term elasticity for estimating the demand for water for domestic use is around -0.27 and long term elasticity is -0.71. The first is less than the second, suggesting that consumers react primarily to continued increases in rates and not variations of a month. The permanence of higher prices warns individuals an ability to adapt after a month to adjust their consumption. His explanation is based on the existence of certain persistence in the consumption habits of domestic users caused in part by the low variation in water prices; as well as psychological and technological reasons that cause a gradual process of adaptation of the behavior of consumers due increases in water rates [15, 28]. Schleich and Hillenbrand [29] suggest that possibly the results of the elasticities of more recent works show a downtrend because the rates represent a small proportion of household income and is associated with member countries of the OECD as the case from Mexico.

An important aspect to distinguish is that endogeneity may originate because the price is considered as exogenous variable, which is related to water consumption, and if not treated with appropriate econometric techniques leads to partial estimators and inefficient. However, given we use a database added by representative community, Shin [30] argues that this problem is not as serious in equations using aggregate as the original source, compared with the functions that use microdata by the effect of synchronization given by the existence of the correlation between price and the error term.

Table 4. Estimates of the dynamic function

Variable	Model 1			Model 2		
	Coefficient	t-ratio	Prob.	Coeficiente	t-ratio	Prob.
Constant	0.6426	1.4173	0.1572	0.5768	1.2110	0.2940
Lagged consumption	0.6171	13.2977*	0.0000	0.6116	12.2336*	0.0000
AP	-0.2735	-5.9151*	0.0000			
PM				-0.2587	-4.3048*	0.0000
AP/PM				-0.2803	-5.6858*	0.0000
Income	0.1047	1.7747***	0.0767	0.1127	1.8093***	0.0712
Temperature	0.0259	1.3592	0.1748	0.0245	1.2785	0.2018
Precipitation	-0.00015	-2.5679**	0.0106	-0.00015	-2.4170**	0.0161
k				1.0832	4.8567*	0.0000
R^2	0.9253			0.9251		
Test F of fixed effects	13.1292*		0.0000	13.0892*		0.0000
DURBIN-WATSON	2.1497			2.1507		

Note : To compute the ratios t, heterostedasticity robust standard errors were used. * Significant at 1% ; ** Significance at 5 % ; *** Significant at 10%.

Meanwhile, the income elasticity of demand showed the expected positive sign according to economic theory, with a coefficient of 0.10, indicating that for every 1% increase in the income of users of residential water, changes in consumption water experiment increased 0.10 % , therefore , appears an increase in consumption and no change itself, suggesting water as a normal good.

Respect to the environmental variables, the maximum temperature was not significant. Between total monthly rainfall and consumption there is a negative correlation, because when it rains more, users not need irrigate their gardens, or other activities that may satisfy or restrict its realization with the fall of rainwater reducing its water consumption. This variable can not be interpreted directly as proportional, change to make it must transform exponentially, give that the variable is presented by this method of estimation. When converting the variable, the resulting calculation is 0.9998, indicating that for each additional mm of increased demand is reduced by 0.02 %, which is very low. Its low coefficient indicates that variations in precipitation show little impact on consumption decisions of users.

An important aspect is the similarity between these results and the coefficients obtained with the econometric specification that seeks contrast the hypothesis proposed by Shin [13] where consumers respond to perceived price. In this version the price perception parameter is 1.08 and the null hypothesis of $k=0$ con $t=4.8567$ is rejected with 4.8567 at a significance level of 1 % ; the null hypothesis of $k=1$ is accepted with 0.3730, corroborating evidence of consumer reaction to the average price received when water demand. Users believe that the price paid is lower than the actual rate paid for by them. According to Shin (1985), their decisions are based on a perceived price below of the institutional rates. The short term elasticity is -0.26 and -0.67 long term, being very similar to the previous regression.

The short term elasticity is -0.26 and -0.67 long term, very similar to the previous regression. The results of dynamic panel for short term elasticity are within the magnitude of the most recent studies estimate water demand using alternative average price [15] . Musolesi and Nosvelli, [31]; Schleich and Hillenbrand, [29]; Fullerton *et al*, [32]; Younes, [22] and those who use the methodology of price perception like Shin, [13]; Nieswiadomy and Molina, [34]; Kavezeri-Karuaihe *et al*, [35] and Binet *et al*., [36]. Also, this found results are within the range of studies that have econometrically evaluated demand functions for residential use in Mexico with specifications and average price like Jaramillo-

Mosqueira, [37]; Garcia-Salazar and Mora-Flores, [38]; Salazar and Pineda, [39] and Avilés-Polanco *et al*, [40]

4. Conclusions

This research represents relevant quantitative information that should be considered by policy makers to improve their decisión making about water management. The results can provide guidance to those responsible for water management to have better elements when evaluating and redesign water tariffs for residential use, in a context where the consumer has asymmetric information and is too expensive for them to invest time and dedication. Additionally, to find elasticities inelastic price, by increase in water prices, will be generated more income to be used to improve planning of supply, causing the population without access to potable water is benefited and those with connection provide them quality service with responsible use. This scenario has high chances of occurrence, according to the results on the estimation of the willingness to pay to start a program of water conservation in contingent valuation studies applied to the Biosphere Reserve El Vizcaino [41] and Biosphere Reserve Sierra La Laguna [42].

The introduction of a discriminatory pricing policy that considers the seasonal factor (winter and summer) could not be as effective for conservation purposes given the low coefficient. On the other hand, the income elasticity of demand was small and is within the range of literature. Estimates suggest the importance of implementing management instruments such as price, intended as a basis for the evaluated of functions for which they were structured and determined actions that develop rates that satisfying its objectives. An adequate design of the rates system can be complement with social, legal and environmental aspects to improve water management in protected natural areas.

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Abbreviations

The following abbreviations are used in this manuscript:

AP	Average Price
m^3	Cubic meters
PM	Marginal Price
p	Precipitation
t	Temperature
w	Water consumption average per capita residential use.

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