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SECTORIAL ANALYSIS OF WATER FEES AND USE IN TULANCINGO, HIDALGO, MEXICO

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ABSTRACT

Water is an important element for the development of productive activities, though its scarcity will make it more difficult to supply the growing demand of different consumer sectors. The aim of this article was to analyze the water demand of the household, commercial, industrial, agricultural irrigation, and livestock sectors using economic instruments such as water and electricity fees in order to reduce water consumption and achieve rational resource use. A double-log multiple linear regression model was estimated to analyze water demand in the aforementioned sectors using annual data from the municipality of Tulancingo in Hidalgo, Mexico, from 2005 to 2023. The results indicate that, in order to reduce water use by 30 %, the water fee in the household, commercial, and industrial sectors should increase by 54.6, 11.1, and 12.8 %, respectively, whereas to achieve the same reduction in electricity use, the fee in the household, commercial, industrial, agricultural, and livestock sectors must increase by 93.5, 75.4, 35.1, 229, and 71.6 %, indicating that the commercial and industrial sectors are more sensitive to water fees and that the commercial, industrial, and livestock sectors are more sensitive to electricity fees. It is feasible to implement increases in water and electricity fees to reduce water use, particularly in the commercial and industrial sectors.

Keywords: Water scarcity, household sector, commercial and industrial sectors, farming sector, water fees, electricity fees.

INTRODUCTION

According to the National Water Commission and the National Statistics and Geography Institute, in 2020, Mexico had 461 640 hm^3 of renewable water, 126 million people, and a real gross domestic product (GDP) of 20.9 billion MXN (CONAGUA, 2021). The regions of the southeast had 23 % of the population, 68 % of the water, and provided 18 % of the country's GDP. The regions of the north, center, and northwest had 32 % of the country's renewable water, 77 % of the population, and provided 82 % of the GDP. The relevance of these data lies in the regional inequality of the water distribution, the concentration of the population, and the economic activity, which could aggravate the overuse of the country's water resources.

The Tulancingo municipality has a total surface of 290.4 km^2. It is located in the southeast of the state of Hidalgo (20° 05′ 09′′ N and 98° 21′48′′ W) and borders the municipalities of Metepec to the north, Acaxochitlán and Cuautepec to the east, Acatlán and Singuilucan to the west, and Santiago Tulantepec to the south. Its mean annual temperature is 14 °C, and total annual rainfall ranges from 500 to 553 mm. The municipality has two rivers, four bodies of water, one dam, and the Tulancingo Valley aquifer, which is a part of the Golfo Norte basin organism (PMD, 2016; CONAGUA, 2023a).

The Tulancingo municipality contains 8881 economic units, with retail trade, manufacturing industry, temporary accommodation, and food and beverage preparation services being predominant. The economic units employ 29 041 people. The industrial field, with a long-standing tradition that dates back to the early 20th century, stands out mostly in textiles, focused on the manufacturing of clothing, knit fabrics, and acrylic yarn production (PMD, 2016).

In the farming sector, 9272 ha are dedicated to agricultural activities, out of which 60.4 % (5599 ha) are irrigated and 39.6 % (3673 ha) are rainfed (SIAP, 2023). The predominant crops under irrigation are maize grain, grasses and prairies, alfalfa, green forage maize, and green forage oats, whereas the predominant crops under rainfed conditions are grain maize, green forage oat, and grain barley. Likewise, 7292 ha are used for livestock, with the main species being raised are dairy and beef bovines, sheep, pork, and poultry (PMD, 2016).

Water demand in the municipality has grown significantly. Between 2005 and 2023, the number of water connections increased from 5733 to 12 002; commercial connections rose from 1119 to 2620; and industrial connections grew from 146 to 606. These increases represent 109, 134, and 315 % compared to the year 2005 (PNT, 2024).

Droughts in the municipality started becoming constant in 2018 under abnormally dry conditions; in May of 2022, conditions became moderately dry; in October of that same year, they turned into a severe drought; in January and February of 2023, the conditions turned into extreme drought; from that date until February of 2024, it was characterized as a severe drought, and in March of 2024, it became an extreme drought once more (SMN, 2024).

Along with this problem, there is an overuse of the Tulancingo Valley aquifer, which is a water source for the municipalities of Santiago Tulantepec, Acatlán, Cuautepec, Metepec, Tulancingo, Huasca de Ocampo, Singuilucan, and others. This aquifer has an annual underground water deficit of 20.93 hm^3, indicating that there is more water being extracted than replenished through recharging (CONAGUA, 2023a). Water scarcity will make it harder to supply this resource to different consumer sectors, and as a result, it will increase over time.

Some authors have studied the water demand in the household sector (Gam and Rejeb, 2021), the commercial sector (Almendarez-Hernández *et al*., 2015), the industrial sector (Rendón-Contreras *et al*., 2021), and the farming sector (Castro-Ramírez *et al*., 2017). The results of these studies indicate that more efficient water use can be made with the implementation of policies and that an increase in water and electric energy fees can reduce the demand for the resource in the consumer sectors.

Population growth and the economic activity of the Tulancingo Valley will increase the demand for water in the future, and the more severe drought, along with the overuse of the aquifer, will make it harder to satisfactorily supply water. Considering this problem, the aim of the investigation was to analyze the water demand for the household, commercial, industrial, irrigation agriculture, and livestock sectors with economic instruments, such as water and electricity fees, to help reduce water use and reach a rational use of the resource. The hypothesis indicates that the rises in water and electric energy fees reduce water use in these sectors.

MATERIALS AND METHODS

The series of household, commercial, and industrial use and fee data from 2005 to 2023 were provided by the director of the Water and Sewage Commission of the Municipality of Tulancingo (AWUMT) via the National Transparency Platform (PNT, 2024). The average water use in the irrigation agriculture sector (supplied with underground water from springs and wells) was obtained from the National Water Commission (CONAGUA, 2023b). The average water use in the livestock sector was estimated as follows: a) the number of heads of livestock population (bovines, pigs, goats, sheep, and poultry) was multiplied by the per capita use of each species (liters of water a day); b) the result was divided by 1000 to obtain the figure (in m^3); and c) the annual use was obtained by multiplying the daily use by 365 days.

The data on livestock population and the price of beef were taken from the Agri-food and Fisheries Information Service (SIAP, 2023) and the per capita use of each species was taken from the United Nations Food and Agriculture Organization (FAO, 2013). Regarding the water fees for agricultural and livestock use, there is no price as such. However, price of the electricity used to pump water for irrigated agriculture was used as a proxy variable for the water tariff in both sectors. The electricity fee for household, commercial, industrial, and agricultural use for the 2005–2016 period was obtained from the National Institute of Statistics and Geography (INEGI, 2024a), and for 2017–2023, from the Energy Regulation Commission (CRE, 2020).

To measure the income, proxy variables were used. In the household sector, the general minimum wage was used, as it is the income one person earns per day; in the industrial, agricultural, and livestock sectors, the GDP of the secondary activities, agriculture, and livestock breeding and production (including the value of cattle, pigs, goats, sheep, and poultry), respectively, were used. The general minimum wage came from the National Minimum Wage Commission (CONASAMI, 2023), and the GDP came from INEGI (2024b). Temperature and rainfall data were taken from the National Weather Service (SMN, 2024). The average prices of pesticides were retrieved from FAO (2024). The monetary variables were deflated using the National Consumer Price Index (INEGI, 2024b) on a 2018 basis.

Model structure and statistical validation

A double-log Cobb-Douglas model was used so that the parameters associated with the explanatory variables would indicate their respective elasticities (Gujarati and Porter, 2010). The Cobb-Douglas function is stochastically expressed as follows:

$$Y_t = \beta_1 X_{2t}^{\beta_2} X_{3t}^{\beta_3} e^{u_t} \quad (1)$$

The relationship between the dependent variable (Y_t) and the explanatory variables (X_{2t} and X_{3t}) is not linear; therefore, Equation 1 is transformed by applying the natural logarithm to each variable. This gives the multiple linear regression model (Equation 2):

$$lnY_t = ln\beta_1 + \beta_2 lnX_{2t} + \beta_3 lnX_{3t} + u_t \quad (2)$$

The formulation of the models proposed to estimate water demand was based on economic theory and empirical evidence. The determining factors of the demand for a good were the price of the good itself, the price of related goods (complements and substitutes), income, and others (Barkley and Barkley, 2013). Empirically, the work by Guzmán-Soria *et al*. (2013) was considered, which was composed of weather variables, electric energy fees as a complementary good to water in demand in different sectors, and other variables that improve agricultural and livestock productivity as determinants of water demand.

For the household sector, the model was as follows:

$$lnHWU_t = \beta_1 + \beta_2 lnHRWF_t + \beta_3 lnHREF_{t-2} + \beta_4 lnGMW_t + \beta_5 lnTE_t + u_t \quad (3)$$

where, for year *t*, *HWU* is the household average water use (in m^3); *HRWF* is the real average water fee for household use (in MXN m^{-3}); *HREF* is the average real electric energy fee for household use (in MXN kW^{-1} h^{-1}, with a 2-year delay); *GMW* is the general minimum wage (in MXN d^{-1}); *TE* is the temperature (in °C); and *u* is the random error.

For the commercial sector:

$$lnCWU_t = \beta_1 + \beta_2 lnCRWF_{t-3} + \beta_3 lnCREF_{t-3} + \beta_4 lnCWU1_{t-1} + u_t \quad (4)$$

where, for year *t*, *CWU* is the average commercial water use (in m^3); *CRWF* is the real average water fee for commercial use (in MXN m^{-3}, with a three-year delay); *CREF* is the real average electric energy fee for commercial use (in MXN kW^{-1} h^{-1}, with a three-year delay); *CWU1* is the delayed average commercial water use (in m^3, with a three-year delay); and *u* is the random error.

For the industrial sector:

$$lnIWU_t = \beta_1 + \beta_2 lnIRWF_{t-3} + \beta_3 lnIREF_{t-3} + \beta_4 lnGDPSA_t + \beta_5 lnTE3_t + u_t \quad (5)$$

where, for year *t*, *IWU* is the average industrial water use (in m^3); *IRWF* is the real average water fee for industrial use (in MXN m^{-3}, with a three-year delay); *IREF* is the real average electric energy fee for industrial use (in MXN kW^{-1} h^{-1}, with a three-year delay); *GDPSA* is the real GDP of secondary activities (in millions of MXN); *TE3* is the temperature (in °C); and *u* is the random error.

For the agricultural irrigation sector:

$$lnAWU_t = \beta_1 + \beta_2 lnAEF_{t-1} + \beta_3 lnGDPA_{t-3} + \beta_4 lnPRP_t + \beta_5 lnPP1_{t-1} + u_t \quad (6)$$

where, for year *t, AWU* is the average water use for agricultural use under irrigation (in thousands of m^3); *AEF* is the average fee for electric energy for agricultural use (in MXN kW^{-1} h^{-1}, with a one-year delay); *GDPA* is the real GDP of agriculture (in millions of MXN, with a three-year delay); *PRP* is the real average price for pesticides (in MXN Mg^{-1}); *PP1* is rainfall (in mm, with a one-year delay); and *u* is the random error.

For the livestock sector:

$$lnLWU_t = \beta_1 + \beta_2 lnLREF_t + \beta_3 lnGDPL_{t-3} + \beta_4 lnPBEEF_{t-2} + \beta_5 lnPP_t + u_t \quad (7)$$

where, for year *t, LWU* is the average water use for the livestock sector (in m^3); *LREF* is the real average electric energy fee for agricultural use (in MXN kW^{-1} h^{-1}, with a three-year delay); *GDPL* is the real GDP for the raising and exploitation of livestock (in millions of MXN, with a three-year delay); *PBEEF* is the price of beef (in MXN kg^{-1}, with a two-year delay); *PP* is rainfall (in mm), and *u* is the random error.

The parameters were estimated by Ordinary Least Squares (OLS) with robust standard deviations, using the R software (R Core Team, 2023). The results were economically and statistically validated, considering the following criteria: a) the estimated parameters were proven to display the expected sign according to the economic theory, and b) statistical tests were carried out, such as Student's *t* and Fisher's test (F), to determine the global significance of the parameters, the Shapiro-Wilk (SW) test for the normality of the residues, the Breusch-Pagan (BP) test for the absence of heteroscedasticity, and the Durbin-Watson (DW) and Breusch-Gofrey (BG) statistics for the absence of first-order and serial autocorrelation, respectively.
The models were validated by comparing the estimated values of the dependent variable with the value observed in reality. A difference of less than 10 % was considered useful to create predictive scenarios in which the water demand of different consumer

sectors decreases by 10, 20, and 30 %. Similarly, the degree to which water and electric energy fees must rise in order to achieve such reductions in water use was determined.

RESULTS AND DISCUSSION

From the point of view of the economic theory, the relationship that must exist between the dependent and independent variables of the method was fulfilled. The coefficients of determination (R^2) vary from 0.71 to 0.94, indicating an acceptable goodness-of-fit between the observed values and those predicted by the model. Similarly, the Student *t* statistic was greater than the unit in absolute terms, indicating that the estimated parameters are significant at the individual level. Considering a 5 % statistical significance ($p \leq 0.05$), the probabilities of the other statistical tests (F, SW, DW, BG, and BP) displayed the following statements in all models: a) that there is global significance of the parameters and at least one of the parameters is different from zero; b) that the errors have a normal distribution; c) that there are no self-correlation issues, no first-order or serial issues; and d) that there are no heteroscedasticity problems (Table 1).

Due to the above, the models proposed were valid, both economically and statistically, and can be used to predict behaviors of the use of water in each of the sectors (endogenous variables of the model) in the face of any change in their exogenous variables.

If a 1 % increase is considered for exogenous variables *HRWF*, *HREF*, *GMW*, and *TE*, *ceteris paribus*, the effects on the water use for households (*HWU*) are as follows: 0.55 % reduction, 0.32 % reduction, 0.93 % increase, and 0.74 % increase, respectively (Table 1). These results indicate that household water use is inelastic against water fees. Additionally, they suggest that water is a complementary good of electric energy, since the use of household appliances such as washing machines and dishwashers, which simplify household chores, is associated with a greater use of water.

According to Reynaud *et al*. (2018), the price elasticity of the demand for household water is -0.7. On the other hand, Bautista-Mayorga *et al*. (2023) estimated elasticity coefficients of -0.588 for water use in regard to the use of household electric energy and 0.235 in regard to the income. Likewise, Reynaud *et al*. (2018) found an elasticity of 0.776 between water use and the mean temperature. Altogether, these findings help conclude that water is a normal good, given that its use increases with income. In addition, temperature is confirmed as a relevant factor in the household use of water.

In commercial use of water (*CWU*), a 1 % change in the exogenous variables *CRWF*, *CREF*, and *CWU1*, *ceteris paribus*, leads to the following changes in use: 2.69 % reduction, 0.4 % decrease, and 0.71 % increase, respectively. In earlier studies, Gracia-de Rentería *et al*. (2021) reported price elasticities related to activities in the tertiary sector of -1.08 for professional services and -1.24 for real estate. In turn, Gómez-Ugalde *et al*. (2012) found a price elasticity of water demand for commercial use of -1.03, as well as an elasticity regarding electric energy of -0.25. Although the latter study did not determine the elasticity associated with the endogenous variable with one year of delay (*t*-1), a direct effect on the use of water was identified in the current period (*t*).

Table 1. Elasticity of water use in the household, commercial, industrial, agricultural, and livestock sectors in the municipality of Tulancingo in Hidalgo, Mexico.

Endogenous variables	Intercept	Exogenous variables				R^2	Probabilities				
							F	SW	DW	BG	BP
		HRWF	*HREF*	*GMW*	*TE*						
HWU	8.52	-0.55	-0.32	0.93	0.74	0.90	0.000	0.24	0.90	0.07	0.22
Standard error	1.63	0.24	0.09	0.28	0.81						
t statistic	5.23	-2.27	-3.65	3.35	0.91						
		CRWF	*CREF*	*CWU1*							
CWU	9.70	-2.69	-0.40	0.71		0.94	0.000	0.11	0.22	0.34	0.49
Standard error	1.95	0.60	0.12	0.07							
t statistic	4.98	-4.49	-3.37	9.87							
		IRWF	*IREF*	*GDPSA*	*TE3*						
IWU	-28.85	-2.35	-0.85	3.31	2.57	0.71	0.006	0.67	0.14	0.30	0.77
Standard error	13.63	1.64	0.53	0.97	1.84						
t statistic	-2.12	-1.43	-1.62	3.43	1.39						
		AEF	*GDPA*	*PRP*	*PP1*						
AWU	11.61	-0.13	0.32	-0.25	-0.33	0.73	0.004	0.91	0.75	0.79	0.14
Standard error	1.77	0.06	0.20	0.06	0.11						
t statistic	6.54	-2.08	1.61	-4.13	-2.99						
		LREF	*GDPL*	*PBEEF*	*PP*						
LWU	-16.09	-0.42	2.84	2.32	-0.96	0.81	0.001	0.26	0.15	0.08	0.57
Standard error	7.52	0.09	0.72	0.40	0.30						
t statistic	-2.14	-4.41	3.96	5.86	-3.22						

Endogenous water use variables: *HWU*: household use; *CWU*: commercial use; *IWU*: industrial use; *AWU*: for agricultural irrigation; *LWU*: livestock use. Exogenous variables: *HRWF*: real average water fee for household use; *HREF*: real average electric energy fee for household use; *GMW*: general minimum wage; *TE*: mean atmospheric temperature; *CRWF*: real average water fee for commercial use; *CREF*: real average electric energy fee for commercial use; *CWU1*: delayed average commercial use of water; *IRWF*: real average industrial use of water; *IREF*: average industrial use of electric energy; *GDPSA*: real gross domestic product (GDP) of secondary activities; *TE3*: mean atmospheric temperature; *AEF*: average electric energy fee for agricultural use; *GDPA*: real agriculture GDP; *PRP*: average pesticide price; *PP1*: rainfall; *LREF*: real average electric energy fee for agricultural use; *GDPL*: real GDP of the raising and exploitation of livestock; *PBEEF*: price of beef; *PP*: rainfall. Probabilities: F: Fisher's test; SW: Shapiro-Wilk; BP: Breusch-Pagan; DW: Durbin-Watson; BG: Breusch-Gofrey.

Differences were observed in the magnitude of the coefficients of elasticity related to the price of water and electric energy, particularly in relation to the price elasticity of the demand. These differences may be attributed to the treatment of the data and the method used in the estimations. However, despite these discrepancies, all studies coincide in the same conclusions: the use of water in the commercial sector displays an elastic behavior, and electric energy acts as a complementary good to water. Therefore, water use is sensitive to changes in price, which suggests that the amount used can be reduced with an adequate price policy.

In the water use for industry (*IWU*), a 1 % change in the exogenous variables *IRWF*, *IREF*, *GDPSA*, and *TE3*, *ceteris paribus*, would have the following effects: 2.35 % reduction, 0.85 % reduction, 3.31 % increase, and 2.57 % increase, respectively. Tobarra-González (2018) reported a water price elasticity for the paper industry of -3.17, displaying a high sensitivity of the consumer to price variations. On the other hand, Bautista-Mayorga *et al*. (2023) identified coefficients related to electric energy, income, and temperature of -0.156, 0.104, and 0.911, respectively.

Significant differences were observed between coefficients in this study and those reported by the authors cited, which may be due to the method used and specific special factors. Nevertheless, the water for industrial use is confirmed to respond elastically to the price of water. Additionally, there is clear evidence of a strong inverse relationship between water consumption and electricity consumption, suggesting that these are complementary goods. The *GDPSA*, used as an approximation of income in this sector, allows water to be classified as a normal good. On the other hand, temperature also plays a crucial part in the use of water. Consequently, the use of water and electric energy fees is suggested as economic policy instruments to incentivize the reduction of water use in the industrial sector. Regarding the variables of income and temperature, their control is more limited since they depend on the general economic surroundings and on the local weather conditions.

For water use in agriculture (*AWU*), a 1 % change in the exogenous variables *AEF*, *GDPA*, *PRP,* and *PP1*, *ceteris paribus*, leads to the following variations in this use: 0.13 % reduction, 0.32 % increase, 0.25 % reduction, and 0.33 % reduction, respectively. Several studies back these findings; Bruno and Jessoe (2021) found a price elasticity in the demand for water agriculture of -0.15, indicating that this demand is inelastic to variations in price. Likewise, Torres-Sombra *et al*. (2013) identified a direct relation between the GDP per capita and the demand for water in agriculture: for every MXN that GDP increases, the demand for water in Sinaloa rises by 0.447 hm^3. Guzmán-Soria *et al*. (2010) found an elasticity regarding the use of fertilizers of -0.315. On the other hand, Khorchani *et al*. (2024), using a correlation matrix, found a positive relation of 0.67 between the yield of rainfed maize and the contribution of water (rainfall plus irrigation).

These results suggest that the use of water in agriculture responds inelastically to the electric energy fee, which is used as a proxy variable for the price of water due to the lack of specific price data over the period of analysis. Additionally, a direct relation is observed with the agricultural GDP (*GDPA*), which helps classify water as a normal good. On the other hand, the reverse relation between the average price of pesticides and agricultural water use suggests that if the price of pesticides decreases, farmers may be incentivized to grow more crops in a larger plot, which would increase water use. By contrast, an increase in the price of pesticides could reduce their use, thus reducing productivity and leading farmers to plant less, reducing water use. Finally, the weather is one of the factors with the greatest repercussions on the yield of agricultural crops, as well as being one of the elements that generates the most uncertainty in terms of decision-making (Khorchani *et al*., 2024).

Finally, a 1 % increase in the exogenous variables *LREF*, *GDPL*, *PBEEF*, and *PP*, *ceteris paribus*, brings about the following changes in the water use for livestock (LWU): 0.42 % reduction, 2.84 % increase, 2.32 % increase, and 0.96 % reduction, respectively. Torres-Sombra *et al.* (2013) found elasticities related to the price of water and electric energy in this sector of -0.065 and 0.051, which are different from the results found and which may be due to the methods used. Guzmán-Soria *et al.* (2010) found an elasticity in milk of 0.0001 and point out that the final products (milk and meat) impact the use of water in the livestock sector.

In the period of study, the agricultural, household, and commercial sectors used 12.5 million, 790 and 263 thousand m^3 of water, whereas the livestock and industrial sectors demanded 105 and 87 thousand m^3 of water (Table 2). With a total demand of approximately 13.8 hm^3 of water, the situation of the aquifer of the municipality of Tulancingo is one of overuse, indicating that a reduction in demand is required.

Table 2. Increase scenarios in water and electricity fees to reduce water use in Tulancingo municipality in Hidalgo, Mexico.

Indicator	Water use per sector (m^3)				
	Household	Commercial	Industrial	Agricultural	Livestock
Observed use	790 353	263 030	87 038	12 515 110	105 789
Estimated use	815 832	285 788	90 859	12 242 000	95 417
Difference	25 479	22 758	3821	-273 110	-10 372
Difference (%)	3.2	8.7	4.4	-2.2	-9.8
Reduction in use (%)	Increase in water fee (%)				
10	18.2	3.7	4.3		
20	36.4	7.4	8.5		
30	54.6	11.1	12.8		
Reduction in use (%)	Increase in electricity fee (%)				
10	31.2	25.1	11.7	76.3	23.9
20	62.3	50.3	23.4	152.7	47.7
30	93.5	75.4	35.1	229.0	71.6

The validation of the models revealed differences of less than 10 % between estimated and observed values. A difference with a positive/negative sign indicates that the model overestimated or underestimated water use in comparison to the observed value (Table 2). Thus, it was possible to develop scenarios to determine the water and electricity fees required to reduce water consumption. If the goal is to reduce household water consumption by 10, 20, or 30 % in terms of estimated value, the fee must rise by 18.2, 36.4, and 54.6 %, respectively. To achieve these commercial water use reductions, water fees must increase by 3.7, 7.4, and 11.1 %. Similarly, to reduce industrial use, the fee must be increased by 4.3, 8.5, and 12.8 %, respectively (Table 2).

The use of water in each sector can be reduced by raising the electric fee. To reduce household water consumption by 10, 20, and 30 %, electricity rates must rise by 31.2, 62.3, and 93.5 %, respectively. For the commercial sector, the fee must increase by 25.1, 50.3, and 75.4 %. Finally, in order to reduce industrial water use, the fee must increase by 11.7, 23.4, and 35.1 %, respectively. For agricultural water use, the fee must increase by 76.3, 152.7, and 229 %. Similarly, the fee for using water for livestock must increase by 23.9, 47.7, and 71.6 %, respectively (Table 2).

Other authors found that increasing the water fee can lead to a decrease in water consumption. According to Bautista-Mayorga *et al*. (2023), in order to reduce water consumption by 10 and 20 % in the household and industrial sectors, the household sector fee must increase by 53.1 and 106.3 %, respectively, while the industrial sector fee must increase by 57.7 and 115.4 %. According to Gómez-Ugalde *et al*. (2012), a 10 % increase in water fees would result in a 10.3 % bimonthly decrease in commercial water demand. Bruno and Jessoe (2021) found a price elasticity of -0.15 for agricultural water use, implying that a 66.7 % increase in price would be required to reduce water use by 10 %. Torres-Sombra *et al*. (2013) observed that reducing water in the livestock sector by 5 % would result in a 76.9 % increase in price.

The authors below found that increasing the electric energy fee makes it possible to reduce water use. Bautista-Mayorga *et al*. (2023) discovered that in order to reduce water use in the household and industrial sectors by 10 and 20 %, respectively, the electricity fee in the household sector must rise by 17 and 34 %, and in the industrial sector by 64.3 and 128.6 %. Gómez-Ugalde *et al*. (2012) discovered an elasticity associated with electric energy of -0.25, implying that in order to reduce water use by 10 and 20 %, the price of electric energy must rise by 40 and 80 %, respectively.

An economic policy would be most effective in the commercial and industrial sectors if water fee increases were considered, and in the commercial, industrial, and livestock sectors if electricity fee increases were considered. This is because the price and cross-price elasticity coefficients were determined to be elastic. Water and electric energy fees in the household sector were higher than in previous sectors, which can be attributed to the critical importance of water and the lack of price elasticity in its demand. The agricultural sector saw significant increases in water fees, which could be attributed to the following: a) electric energy is subsidized in Mexico; b) the inelastic elasticity coefficient is associated with electricity (used as a proxy variable for the water fee); and c) the water use value in agriculture is lower than in other consumer sectors.

CONCLUSIONS

The analysis of water demand for the water-using sectors in the municipality of Tulancingo revealed that increasing water and electricity fees is a feasible way to reduce water consumption. The commercial and industrial sectors are especially sensitive to increases in water fees, while the commercial, industrial, and livestock sectors are more sensitive to increases in electricity fees. Reducing water use or demand in drought-prone areas benefits future generations by allowing them to use water more wisely.

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