Economic valuation of drinking water quality in Aguascalientes, Ags, Mexico

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ABSTRACT
Objective: To estimate the economic valuation of inhabitants of Aguascalientes, Mexico, to improve the quality of the drinking water service.
Design/methodology/approach: The contingent valuation method was used through a questionnaire that incorporated socioeconomic variables and questions about willingness to pay. It was applied to a sample of n=160 users, selected with simple random sampling in the municipality of Aguascalientes.
Results: The results show that heads of family are willing to pay on average $189 pesos monthly to contribute to improving the quality of the drinking water service; likewise, variables such as days when they receive water, perception of the fee, age, improvement of the quality, and sufficiency of the water they receive were identified as relevant in the willingness to pay. Factors such as marital status, occupation, and gender were not relevant for such willingness.
Findings/conclusions: There is high acceptance among heads of family towards initiatives to improve the drinking water quality, which indicates a significant awareness regarding the importance of preserving the quality of the water resource and a tangible willingness to participate in its recovery.

Keywords: Contingent valuation, willingness to pay, water policy.

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INTRODUCTION

Factors such as climate change associated with the increase in population, the use of water for waste dissolution, and the contamination generated by anthropogenic activities contribute to its scarcity and deterioration, making it inappropriate for most uses (Naciones Unidas, 2024).

Distribution problems, as well as difficulties related to the quality and quantity of water, continue to affect rural zones and regions with high water pressure. The limited availability of this resource is closely linked to poverty, with repercussions in health, food production, and gender equity, which finally lead to its exclusion (Soares, 2021).

Something to emphasize is that the main consumers of water in Mexico are agriculture with 76% and public supply with 14%, while the remaining 10% is distributed between industry and thermoelectric plants (INEGI, 2020a).

In 1995, the municipality of Aguascalientes had a population of 582,827 inhabitants, whereas by 2020 the population was 948,990 inhabitants. This shows that demographic growth in 30 years is a direct factor on the overexploitation of aquifers (INEGI, 1995; INEGI, 2020b).

In October 2023, the municipality acquired the service of drinking water and sewage. Based on an integral analysis about legal, technical, commercial and financial aspects, the Integral Waters Model of Aguascalientes (Modelo Integral de Aguas de Aguascalientes, MIAA, 2023) emerged, to operate the services.

CONEVAL places Aguascalientes as the number one state in the Mexican Republic in drinking water coverage at the national level (99.1%), followed by Colima (99%) and Tlaxcala (98.9%) (Alva, 2021). In contrast with the national average of 73% of the households with drinking water piping, Aguascalientes has 93.7% households with this service (INEGI, 2017); however, it faces specific challenges in terms of availability and quality of the drinking water. Located in a semi-arid region, its main source of supply comes from the Aguascalientes Valley and underground wells, which have shown signs of overexploitation and deterioration of the water quality (CONAGUA, 2024).

The growing water demand, together with the contamination of important bodies of water in the state, such as the San Pedro River, have generated worry over the sustainability of the resource and the need to improve infrastructure and management of drinking water in the state. Based on this, the economic valuation of inhabitants in Aguascalientes, Mexico, was estimated, to improve the quality of the drinking water service.

MATERIALS AND METHODS

The state of Aguascalientes is made up of 11 municipalities and covers a surface area of 5,615.7 km^2, which represents 0.3% of the national territory. Its population amounts to 1,425,607 inhabitants, equivalent to 1.1% of the national total (INEGI, 2020c). Based on the census carried out by INEGI (2020b), the municipality of Aguascalientes had a population of 948,990 inhabitants.

The zone where the study was conducted is found along the Aguascalientes Valley (0101), which belongs to the Administrative Hydrological Region VIII Lerma-Santiago-Pacífico and stretches almost completely within the municipality of Aguascalientes, with a territorial extension of 5,617 km^2. The region's climate is mainly semi-dry, with mean annual temperature of 17.4 °C and average precipitation of 526 mm (INAGUA, 2023).

Willingness to pay (WTP) by the heads of households of the municipality for water quality improvement in the drinking water service was estimated through the method of contingent valuation (CVM). This technique has the aim of quantifying individual WTP in face of changes in the quantity or quality of goods and services, as well as identifying the influence of socioeconomic variables on that willingness. According to Young and Loomis (2014), the CVM is especially adequate to value non-commercial benefits of water, such as the ones that are analyzed in this study. For data collection, a simple random sampling for finite populations was used, using the formula suggested by Aguilar (2005), and considering the variables of level of confidence and margin of error suggested by Cochran (1985), expressed in the following way:

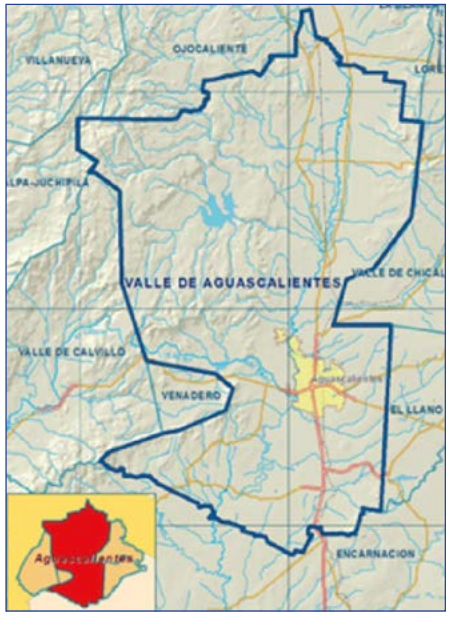

Figure 1. Zone of the Aguascalientes Valley. Source: CONAGUA.

$$n_0 = \frac{Z^2 Npq}{(N-1)d^2 + Z^2 pq} \quad (1)$$

Where: n_0 represents the size of the sample (96 surveys), while N corresponds to the total size of the population (948,990 inhabitants). The level of confidence used was 95% (Z=1.96). Parameter d reflects the absolute level of accuracy (0.1), p corresponds to the proportion of the phenomenon estimated in the population referenced (0.5), and q denotes the proportion of individuals in the reference population that does not present this phenomenon (0.5).

A pilot sample was defined in form of open question, where the participants were requested to indicate the monetary amount that they would be willing to pay without predefined options.

The objective of this phase was to establish the superior and inferior limits of WTP. From the results obtained, the final version of the questionnaire was made with a simple dichotomous format where the questions about willingness to pay included response options, which allowed to reduce possible biases. Based on the data from the pilot test, a series of fees was established that were proportionally distributed between the surveys applied. The values considered were: 50, 100, 150 and 200 pesos monthly.

The survey was made up of four sections and 26 questions. The first section refers to data of control and classification of the questionnaires, ensuring that the questionnaires are consistent and the data are structured adequately for their analysis. The second section of the survey seeks to obtain information about aspects related to the water resource, how they perceive the quality, and the sufficiency of drinking water. In the third part, interview respondents are explained the problems associated with using poor quality water

for human consumption. Once this scenario is explained, there are questions about the monetary willingness to pay for a project to improve the quality of the drinking water service, and in case it is negative, interviewees are asked about the reasons. In the last section, the socioeconomic information of the survey respondent is gathered.

The final sample used in the study consisted of n=180 validated questionnaires, after having dismissed 20 for various reasons that are explained next. During the validation process, it was identified that eight interview respondents presented a behavior of protest when asked about their WTP; that is, although they answered affirmatively, they refused to indicate a specific amount from the options proposed in the questionnaire. Also, six questionnaires were excluded because the interviewees showed strategic behavior by declaring exceedingly high amounts. The six remaining questionnaires were eliminated due to mistakes made while completing them, by the staff in charge of applying them. However, n=160 questionnaires were considered to carry out the study.

The information gathered from the total number of questionnaires was captured in a MS Excel spreadsheet, while the econometric analysis of the database was carried out using the NLogit software through the method of maximum authenticity to estimate the probability of willingness to pay. Different models were evaluated with the objective of defining which variables more accurately explain WTP related with improving the quality of water from the San Pedro River. For this purpose, a Logit type model was used.

The econometric model that WTP describes to improve the quality of the river's water can be expressed in the following way:

$$P(SI) = \beta_0 + \beta_1 AMOUNT + \beta_2 AGE + \beta_3 PERCUO + \beta_4 DAYS + \beta_5 CAL + \beta_6 SUF + \varepsilon \quad (2)$$

In this equation, P(SI) is a dichotomous dependent variable that indicates the probability of the answer being YES=1 or NO=0, while the other variables are independent (see Table 1).

Calculating the average WTP was carried out using the following formula:

$$WTP_{media} = \frac{\sum_{i=1}^{n} \frac{\beta_0 + \beta_2 AGE + \beta_3 PERCUO + \beta_4 DAYS + \beta_5 CAL + \beta_6 SUF}{\beta_1 AMOUNT}}{n} \quad (3)$$

RESULTS AND DISCUSSION

The results are presented in the following order: 1) profile and characteristics of the survey respondents, and 2) characteristics of the model. The surveys were conducted completely in the municipality of Aguascalientes, because most of the population in the state resides the capital municipality. Initially, results from the main descriptive statistics corresponding to the most relevant variables from the study were presented (Table 2).

Table 1. Definition of the variables used in the study.

Variable	Definition	Unit	Scale
WTP	Willingness to pay (NO=0, YES=1)	Dichotomous	Ordinal
AMOUNT	Amount available for payment	Pesos	Discreet
AGE	Age of interviewee	Years	Discreet
PERCUO	Perception of water rates (Low=0, Adequate=1, High=2)	Dichotomous	Ordinal
DAYS	Days per week with access to drinking water (1 to 3=0, 3 to 5=1, Every day=2)	Dichotomous	Ordinal
CAL	Perception of water quality (Poor=0, Fair=1, Good=2)	Dichotomous	Ordinal
SUF	Sufficiency of water supply (NO=0, YES=1)	Dichotomous	Ordinal

Source: Prepared by the authors.

Table 2. Descriptive statistics of the research variables.

Variable	Average	Standard deviation	Maximum value	Minimum value	Coefficients
WTP	0.6062	0.4901	1	0	9.3241
AMOUNT	125	56.0772	200	50	−0.0147
AGE	41.5688	13.1233	73	18	−0.0600
PERCUO	0.9687	0.6483	2	0	−3.1602
DAYS	0.7625	0.8047	2	0	1.7394
CAL	0.9062	0.8452	2	0	−1.2690
SUF	0.3687	0.4839	1	0	−3.1179

Source: Prepared by the authors.

The information was processed with the NLOGIT software using the maximum likelihood method to estimate the probability of willingness to pay. Different Logit-type models were evaluated with the objective of identifying the variables that best explain WTP due to the improvement of water quality of the public service.

In discrete binary selection models, it is common to use an average analogous to the R^2 coefficient of determination, with the aim of evaluating the general degree of adjustment of the model. This statistic is known as pseudo-R^2 by McFadden, and it is calculated in the following way (Valdivia *et al.*, 2009):

$$pseudo\, R^2 = 1 - \frac{LnL}{LnL_0} \tag{4}$$

Where: LnL represents the likelihood function under the restriction that all the parameters are equal to zero, and LnL_0 corresponds to the same function evaluated for the model without restrictions, calculated through the following expression:

$$LnL_0 = n\left[PLnP + (1-P)\,Ln(1-P)\right] \tag{5}$$

Where: P represents the proportion of affirmative responses obtained in the survey regarding the question about WTP, and n corresponds to the size of the sample. Making the pertinent calculations, the result was that: $LnL_0 = -107.26$; when $LogL$ was solved, the value was: $LnL = -48.90$.

Substituting the data in (5), a pseudo-R^2 of $0.5440 \approx 0.54$ was obtained. Therefore, the model was considered acceptable, since in an adjustment higher than 0.1, it is considered satisfactory (Bateman, cited by Valdivia *et al.*, 2009).

The model of estimated probability $[P(SI)]$ was:

$$P(SI) = 9.3241 - 0.014\,AMOUNT - 0.06\,AGE - 3.16\,PERCUO + 1.7394\,DAYS - 1.269\,CAL - 3.1179\,SUF$$

To analyze each parameter of the model, the marginal effects were considered, which are a measurement of the instantaneous effect in face of unitary change in an independent variable, which it has on the prediction of the probability that P_i is equal to one, when all the variables remain constant.

Assuming the logistic distribution as (6): This way, the marginal change rate in the probability of occurrence of the event in face of changes in the explicative variables was (7) (Gujarati, 2004):

$$P_i = \frac{e^{z_i}}{1 + e^{z_i}} \tag{6}$$

$$\frac{dP_i}{dX_i} = \beta_1 P_1 (1 - P_1) \tag{7}$$

After codifying the information of the surveys in the NLOGIT software, the marginal effects were obtained (see Table 3); based on the exit of the software, the most influential variable in WTP was perception of the fee (PERCDECUO). That is, the perception that survey respondents have about the perception of the fee is the factor that most reduces the probability of them being willing to pay it; therefore, if they consider that the fee is unfair or high, this impacts their decision strongly, with 63.6%. However, as the amount of the fee increases, the probability of response decreases by approximately 0.297% for each monetary unit. On the other hand, for each additional year in age, the probability of positive response decreases 1.2%; that is, the older survey respondents are less prone to pay. Likewise, a worse perception of the water quality reduces the probability of payment by 25.5%, which could be because they do not want to pay for a service of bad quality. In contrast, if they consider that water is not enough, their WTP decreases by 62.5%; that is, if they do not receive enough, they are not willing to pay. However, for each additional day when they receive water, the probability increases by 34.9%; that is, with greater continuity in the service, the WTP will be higher.

Table 3. Marginal effects.

Variable	Comments
CONST	1.87557
AMOUNT	−.00297
AGE	−.01208
PERCUO	−.63569
DAYS	.34989
CAL	−.25527
SUF	−.62554

Source: Prepared by the authors.

As presented in Figure 2, perceptions about the cost of the drinking water service directly influenced people's WTP. Those who perceived the fee as "high" had a negative average WTP of −84.66, which indicates a lower willingness to carry out additional payments. On the other hand, those who considered that the fee was "low" showed a significantly higher average WTP, of 454.49, which reflects greater willingness to contribute economically. In the case of the people who qualified the fee as "average", the average WTP was 178.12, representing an intermediate point between the two extreme opinions. This translates into how individual perceptions of the cost can notably modify the attitude towards additional payments.

The responses reflected that the average WTP varies according to the frequency of access to drinking water. Those who indicated having limited access to drinking water during 1 to 3 days per week showed higher average WTP, with a value of 235.89. On the other hand, the people who reported having access 3 to 5 days per week reflected a lower average WTP, of 152.77. Finally, those who have daily access to drinking water represented the lowest average WTP, of 135.87.

This suggests that the people with significant restrictions on the supply are more motivated to contribute economically, probably due to the perception of greater need to improve access to the resource. In contrast, those with more regular supply have lower willingness to make additional payments, possibly because they perceive that their basic needs are already being covered.

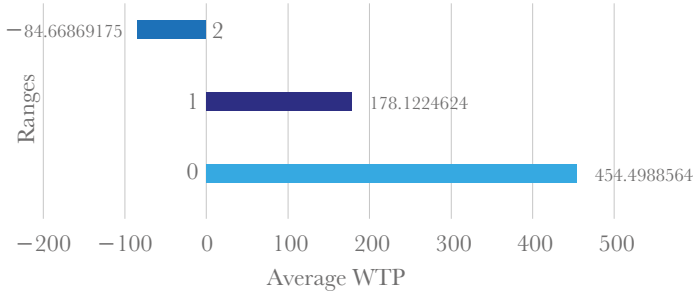

Figure 2. Perception of the average fee.
Source: Prepared by the authors.

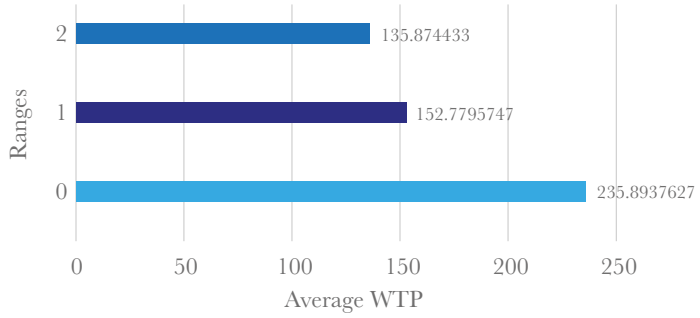

Figure 3. Average WTP of the variable Days.
Source: Prepared by the authors

The data obtained indicated that perception of the quality of drinking water significantly influences WTP. The people who consider that drinking water is of poor quality present the highest average WTP, with a value of 308.16. This could reflect a greater preoccupation over improving the quality of the water resource. On the other hand, those who perceived water as being of good quality have a much lower average WTP, of 91.70, possibly because they are already satisfied with the service and do not feel the urgent need to contribute to its improvement. Those who grade it as having "average" quality show an average WTP of 126.37, between both extremes.

This can be translated into a higher willingness to pay when people perceive significant problems in water quality, which makes a connection between perception of the resource and interest in investing in its improvement.

The average WTP was calculated through:

$$WTP_{media} = -\frac{\alpha}{\beta} = -\frac{2.7927}{-0.0147} = 189.39 \approx 189$$

Where: α is the sum of the coefficients of independent variables multiplied by their average values, including the ordinate of the origin 0 (β_0), and β corresponds to the coefficient of the variable PRECIO, which has a negative sign.

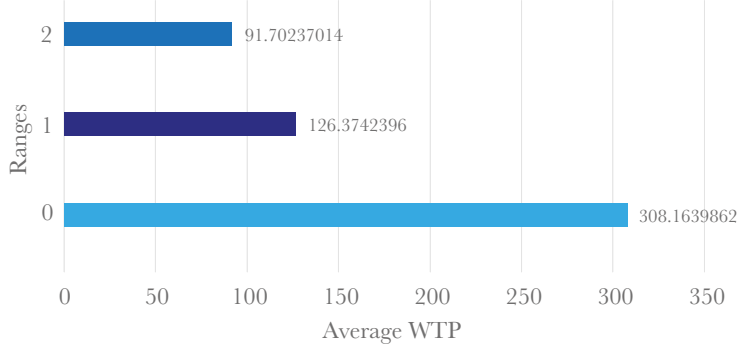

Figure 4. Average WTP of the variable Quality.
Source: Prepared by the authors.

The amount 189 indicates the compensated variation or willingness to pay in Mexican pesos that each of the heads of households from the municipality of Aguascalientes would be willing to offer monthly for improvement of the quality of the drinking water service.

When the results are extrapolated to the totality of the inhabitants of the three communities used in the study, a monthly income flow of $179,359,110 destined to financing the project was estimated.

The results obtained are consistent with previous studies, which have applied the method of contingent valuation, such as the study conducted in the National Molino de Flores Park (Tudela *et al.*, 2011), where an annual conservation value of USD $384,000 was estimated and an entry fee of $24 pesos MX. As in that study, it was identified that variables such as income and environmental perception influence WTP. In contrast, variables such as marital status, occupation and gender did not show a significant relationship, which suggests that WTP responds more to the direct experience with the service and perception of the resource, than to general demographic characteristics.

On the other hand, when comparing with the study conducted in Valle de León, Guanajuato (Valdivia *et al.*, 2022), where monthly WTP was estimated to be $182 pesos MX, also using the method of contingent valuation and a Logit-type model. Both cases show similar values, which suggests that, despite regional and demographic differences, there is a common sensitivity around water quality and the willingness to finance improvements. In León, the total estimated annual value is $1,034 million, representing a solid basis to evaluate investments in infrastructure, which could be replicated in contexts such as Aguascalientes if similar scales and conditions are considered. The estimation of the economic value of the drinking water service offers a useful quantitative basis to support the formulation of policies related to the use of water management. The willingness to pay obtained could represent a potential source of financing to implement such policies and actions to improve the quality of the public service.

CONCLUSIONS

Inhabitants in the municipality of Aguascalientes perceive and are aware of the problem of water contamination and scarcity, so 60.6% of the interview respondents pointed out that they agree with the WTP to improve the quality of the drinking water service. The variables that explain further the probability of an affirmative response to WTP were the days that they receive water, their perception of the fee, age, improvement of the quality and sufficiency of water that they receive, which are relevant in WTP. In contrast, factors such as marital status, occupation and gender were not relevant with such willingness. The economic valuation by heads of households was $189 pesos monthly. When results are extrapolated to the heads of family of the municipality of Aguascalientes, it is estimated that total willingness to pay would reach $179,359,110 pesos MX monthly.

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