Article

Economic valuation of the quality of drinking water in León, Guanajuato

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Abstract

Water is a natural resource on which there is great pressure and problems in the world and in Mexico. In the aquifer of Valle de León, Guanajuato, there is scarcity, pollution and overdemand by the population of the metropolitan area of the City of León, one of the most populated in the country. Currently, the city is supplied mainly from the aquifers of Valle de León, with the expectation of receiving water from the Zapotillo dam. The objective of the research was to estimate the willingness to pay by consumers of drinking water for a better quality of the water consumed by the inhabitants, which is delivered to households by the Drinking Water and Sewerage System of León. The valuation method used was that of contingent valuation, which allows a monetary amount to be assigned to both the economic value of use and the non-use value (values of existence and legacy). Using a linear random utility model and making it operational through the logistic regression probability model, it was estimated that the willingness to pay of the city's households is $182.00 per month. It is concluded that the estimated annual amount of $1.034 billion represents the consumer surplus on which the costs of building new infrastructure, improving the existing one and incorporating technologies by the agency in charge of the supply of drinking water and sewerage will be evaluated.

Keywords: random utility model, stated preferences, water scarcity, willingness to pay.

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Introduction

Water is a scarce commodity, its scarcity has increased in recent years due to several factors, among which it is possible to mention: the increase in population, the increase in economic activity, its use as a waste diluent and the pollution derived from human activities that renders it unusable for almost all uses. The effects of climate change make the phenomena of scarcity and abundance more frequent.

The competition between different uses at some times and places is strong. Whatever allocation is determined for the water resource, it implies that it will not be available for other uses. In the world there are countries and cities with alarming conditions of lack of water, Mexico is no exception. According to CONAGUA (2018), Mexico only has 1% of fresh water worldwide, receives a rainfall of almost 1.449471 trillion cubic meters and the use of water has two purposes, which are its consumption in the economic sector and the other is the generation of energy. It is also noted that the largest consumers of water are agriculture with 76% and public supply with 14.4%. Mexico incorporated into its legislation the water planning and programming of the global model, through the National Waters Law, in 2004, what has been called 'Integrated Water Resources Management' (Scott and Banister, 2008; Silva *et al*., 2018).

The municipality of León, Guanajuato, in 1990 had a population of 867 120 inhabitants in 148 localities and in 2020 a population of 1 721 215 in 573 localities. That is, in 30 years the population of the municipality almost doubled and settled on a number of localities that grew exponentially (INEGI, 1991; INEGI, 2021). The growth of the municipality of León has been due to the economic growth and development of El Bajío in Guanajuato. In the last decade of the twentieth century, the urbanization and metropolization of rural areas both by industry and services and the population that settles due to the existence of sources of employment.

The demographic, spatial and operational growth has brought to the City of León problems of management and government associated with its development as a metropolis. For example: drinking water supply, wastewater management, provision of communication routes, urban development, recreational development, development of economic and industrial activities, provision of services such as security and health, among others (Khan, 2018).

According to SAPAL (2021), the promise of this municipal agency to the population of the municipality is 'Water forever', its mission 'To provide the services of drinking water, sanitation and use of treated water to the population of the City, with timeliness and sustainability', having as a vision 'To adopt the best practices worldwide related to the supply, distribution and consumption, treatment and reuse of water to guarantee the sustainability of the municipality of León and its metropolitan area'. Also, according to SAPAL (2021), water is extracted from the aquifer of Valle de León with 1 455 wells, of which 247 are located in the City of León and its conurbation area, 29 in Purísima del Rincón, 28 in Silao, 18 in San Francisco del Rincón and the remaining wells are under concession.

In terms of services, according to INEGI (2021), of the 440 870 existing homes in the municipality, 96% have piped water either inside the house or in the respective yard. SAPAL (2021) claims to have a coverage of 98% with a total of water intakes of 476 080. Of these, 94.4% are domestic intakes (449 319), 4.8% are commercial intakes (22 753), 0.5% industrial intakes (2 611) and 0.3% are charity intakes (1 397).

Despite the wide coverage given to the population of the municipality according to SAPAL (2021) itself, water is extracted from wells with a depth of 100 m or more and the municipality suffers from strong water stress, despite the activities carried out to find new sources, improve the regulation of the water market and promote the reuse of the resource. In addition to the above, environmental sustainability actions such as regulation and incorporation of industrial parks, wastewater treatment and discharge control are encouraged. Actions of constant improvement of operation and operational efficiency, energy efficiency with the use of clean energies, training of its human personnel, virtual tenders and actions of transparency and healthy finances are also incorporated.

SAPAL's own income for 2021 for water, sanitation, treated water, incorporation rights and others, such as health services, is $2 317 945 002.00 from its 468 000 customers (SAPAL, 2021). The IPEGEG (2021) defines five metropolitan areas at the state level that do not necessarily coincide with those defined at the federal level. The state metropolitan area of León includes the municipalities of León, Silao de la Victoria, San Francisco del Rincón and Purísima del Rincón.

In the study conducted by Silva *et al*. (2018), it is stated that the drinking water service in León, Guanajuato, is a municipalized service and has been a process of negotiated transfer of water from rural communities that has been carried out through the transfer of management and infrastructure to the municipality.

Given the growth of the city of León and its metropolitan area, the supply of drinking water for the population and for the operation of productive activities and services becomes a challenge and as already mentioned motivates the search for solutions in a wide range of options. One of them, perhaps the most promising, is in the possibility of receiving water from the dam 'El Zapotillo', located in the highlands of Jalisco, however, due to aspects of governance, it is something that is in doubt as to whether this will happen, when it will happen and how much water it will be able to receive.

El Zapotillo dam was intended to provide drinking water for 30 years to benefit a population of 1 411 000 inhabitants (316 000 from 14 municipalities in the Highlands of Jalisco and 1 095 000 inhabitants of the City of León, Guanajuato). The engineering initially determined a dam wall height of 80 m, but later it was contemplated to supply not only the 14 municipalities of Jalisco and the City of León, Guanajuato, but also the conurbation area of Guadalajara. This required that the wall of the dam be not 80 m high but 105 meters in order to obtain a greater volume of water.

This decision would also cause the flooding of the locality of Temacapulín, Jalisco, due to the reservoir of the dam with a wall of 105 m and even though the inhabitants of that locality were offered to increase the containment dam to avoid the flooding of that community, they were dissatisfied and with different organizations defending the environment, non-governmental organizations, among others, have filed and won different amparos, of which they have won some, which has kept the construction of El Zapotillo dam stopped (López, 2012).

The valuation of water has been a much-discussed topic due to the social, cultural, religious and economic implications associated with this resource. However, one of the four 'Dublin Principles', adopted at the 1992 International Conference on Water and the Environment in Dublin, states that 'water has an economic value in all its competitive uses and should be recognized as an economic good'.

Water is a good different from the rest of the goods consumed by individuals due to its special characteristics that impose challenges to different actions, such as the design of management institutions and its allocation, as well as for the formation of markets (Young and Loomis, 2014). Alternative approaches have been developed to analyze resource valuation. Young and Loomis (2014) point out that philosophers distinguish between intrinsic and extrinsic values. Extrinsic ones refer to their contribution to improving human well-being. These values in applied terms have been reflected in measures of well-being that find their practical representation in monetary units. The change in the well-being of an individual to assess a proposed improvement is measured as the maximum amount that that person would be willing to give up in order to achieve that improvement. For a change that reduces well-being, the measure is the minimum amount required to accept the change. So, a criterion accepted by natural resource economists is that the results of a policy must be based on the concept of willingness to pay (WTP).

There are several methods of water valuation. One classification sorted the main methods into four different categories based largely on two criteria. The first grouping criterion is based on whether behavioral observations are carried out through participants' behavior within 'real' markets or whether the behavior is obtained as a hypothetical response to constructed market scenarios. The second criterion is determined by whether the monetary values derived from the technique are observed directly in the markets or simply inferred from behavior and preferences (Aylward *et al*., 2010).

Young and Loomis (2014) identify 17 methods of water valuation, which are applied to different uses of water and different contexts. They propose a taxonomy for their classification divided into two groups: Inductive and deductive methods. The method used in this research, that of contingent valuation, in the first classification is within those of hypothetical behavior. In the second, it is within the inductive ones.

The contingent valuation method has been used to value goods or services that have the characteristics of public goods. According to Aylward *et al*. (2010), it is the most widely used for its flexibility and probably for allowing 'evaluating the total value that includes the passive use value'. Its use includes applications of valuation and willingness to pay (WTP) for natural resources such as national parks (Tudela *et al*., 2009), Biosphere reserves to know the valuation of environmental service (Monroy *et al*., 2011), ecosystem services (Navrud and Strand, 2018), in the valuation of natural and historical places (Tecpan *et al*., 2016), for the creation of a green fund and improve air quality (Hernández *et al*., 2019), for improvements in natural recreational areas (Valdivia *et al*., 2011) and to know the valuation of water in the industrial sector (Valdivia *et al*., 2011), environmental services in urban parks (Hernández *et al*., 2019), among others.

To know the willingness to pay to improve water quality, there are several applications of the contingent valuation method, such as the one carried out by Tudela *et al*. (2009), for the development and proposal of a strategy to treat a case of water affected by fluoride (Roy and Chacaraborty, 2014), to know the willingness to pay for drinking water services in developing countries (Tudela *et al*., 2009), to know the willingness to pay for improvements in the quality of drinking water in rural areas (Cho *et al*., 2005) and to know the willingness to pay for the reduction of water pollution from agricultural activities (Hite *et al*., 2002), among others.

The objective of the research was to estimate the willingness to pay, on the part of consumers of drinking water, for a better quality of the water they consume and that the Drinking Water and Sewerage System of León, Guanajuato (SAPAL) delivers to households.

Materials and methods

According to CONAGUA (2020), the Valle de León aquifer is one of the 22 aquifers that are in Guanajuato and is located at the central-western part of that state on the border with Jalisco, between the parallels 20° 52’ and 21° 22’ north latitude and the meridians 101° 25’ and 101° 50’ west longitude, covering an area of approximately 1 321 km^2. The municipality of León is one of the 46 municipalities of Guanajuato, is located in the west of the state on the borders with Jalisco. It has a territorial extension of 1 221.6 km^2. The total population of the municipality of León is 1 721 215 inhabitants (INEGI, 2021).

The municipality of León is part of the metropolitan area of León, which is the most populated in the state and El Bajío region. It is made up of the municipalities of León and Silao. The localities of the municipality that make it up are the municipal seat, León de los Aldama and those of Duarte, Loza de los Padres, Plan de Ayala, Santa Ana del Conde, Medina, Centro Familiar La Soledad and La Ermita.

The data used in the logistic models to estimate the willingness to pay for a greater quantity and quality of drinking water by consumers in the City of León were obtained from the application of questionnaires to probabilistic sample of users of the drinking water service. Of the 165 questionnaires that were originally available from direct interviews with consumers, 144 were finally used in the logistic regression run. Seven questionnaires were eliminated because the interviewee had a protest behavior when asked about their willingness to pay; that is, they answered affirmatively to the question, but refused to say a specific monetary amount.

Five other questionnaires were also eliminated because it was detected that the interviewee had a strategic behavior, since they provided a very high figure of the amount that they would be willing to pay; that is, with this amount, they behavior showed that they could influence the implementation of the improvement project that was proposed to them in the hypothetical scenario. The other nine questionnaires were removed because they were not filled out correctly by the interviewer.

The design of the applied questionnaire followed the recommendations given in Mitchell and Carson (1989) for the referendum format. The payment card mentioned a price range in which the interviewee could choose a specific amount when answering the question of whether they would be willing to pay for a greater water availability in case they only had water service for a restricted number of hours a day and/or only a few days of the week.

If in one of the first questions posed at the beginning of the questionnaire applied it was detected that the interviewed user had drinking water all week and most hours a day or 24 hours a day, the interviewer proceeded to apply a questionnaire designed to interview them about their willingness to pay for a higher water quality. The price range, which also contained zero, that was proposed to the interviewed user was determined by consulting experts on the subject of water valuation and informal talks with officials indirectly related to the administration of water and sewerage in León, Guanajuato.

The methodological procedure used to obtain the willingness to pay for a greater amount of water by the user of this public service has two supports. The first is the microeconomic argument that has to do with changes in consumer welfare due to improvements in the quality, for example, the provision of amenity and recreational services or the use of a drinking water supply service. Both types of services share the characteristics of public services. Measures of changes in welfare are consumer surpluses studied in the so-called welfare economy.

The first is the Marshallian consumer surplus, which is obtained from the ordinary demand for a good with observable or market prices. The other two types of consumer surpluses are the so-called compensating variation and the equivalent variation. These two types of surpluses are obtained from the compensated demand function and are called, in general, the Hicksian consumer surplus. In methods of economic valuation of, for example, water availability and quality, it is common practice to use the so-called willingness to pay as a monetary approximation to the Hicksian consumer surplus, while the so-called willingness to accept compensation for a loss in consumer welfare is used as an approximation to the Hicksian concept of equivalent variation (Fischel, 1995; Johansson and Kristrom, 2012).

The econometric methodology used to calculate the willingness to pay for a greater amount of water is the logistic regression model. The logistic regression model belongs to the family of generalized linear models that are a generalization of the classical linear regression model that allows modeling response variables that have a distribution of errors different from the normal distribution.

This is usually referred to as greater flexibility in modeling response variables. A fundamental feature of generalized linear models is that the variance is a function of the mean and is not constant as in ordinary regression under the assumption of homoscedasticity (Hardin and Hilbe, 2018). The variables used in the study are shown in Table 1.

Table 1. Definition of the variables used.

Variable	Description of variables	Units	Scale
Dapcag	Willingness to pay for better water quality (No = 0, Yes = 1)	Dichotomous	Ordinal
Mondap	Amount of the willingness to pay	Pesos	Discrete
Ingrehog	Household income	Pesos	Discrete
Gen	Gender (0 = female, 1 = male)	Dichotomous	Ordinal
Edad	Age of the interviewee	Years	Discrete
Nivest	Level of studies	Years	Discrete
Intfam	Family members	Members	Discrete

The data corresponding to the variables amount of willingness to pay for better water quality and income are monthly data.

Results and discussion

The descriptive statistics of the variables used in the run of the linear random utility model are shown in Table 2.

Table 2. Descriptive statistics of the study variables.

Variable	Mean	Standard deviation	Maximum value	Minimum value
Dapcag	0.6527	0.4777	1	0
Mondap	76.8333	53.5486	250	5
Ingrehog	7 510.42	4 339.79	15 000	3 000
Gender	0.5208	0.5013	1	0
Edad	44.8125	12.3373	83	22
Nivest	3.2639	1.7096	8	1
Intfam	4.2152	1.8136	13	1

Based on the output of SAS 9.0.

As can be seen, of a total of 144 interviewees about their willingness to pay to improve the quality of drinking water supplied by the Drinking Water and Sewerage System of León, Guanajuato (SAPAL, for its acronym in Spanish), 65.3% answered affirmatively, while 34.7% answered negatively. The amount of the arithmetic average of the willingness to pay for better water quality was $76.80 per month.

Although in the table of descriptive statistics the indicators of the monthly income of the household are being considered, according to Haab and McConnell (2002), in the procedure to estimate a random utility model as a linear utility function, as it is in this case, a drawback is that income must be eliminated as a determinant of the responses by assuming that the marginal utility of income is constant in all scenarios posed by the contingent valuation questions. Therefore, in the econometric estimation of the willingness to pay, this variable is excluded from the equation specified for the logistic regression model, as will be seen later.

The logistic regression model according to Haab and McConnell (2002) from which the parameters for the estimation of the willingness to pay can be recovered using a linear model of random utility for the study of contingent valuation on the quality of drinking water in the metropolitan area of Valle de León, Guanajuato, is a model with which the expected willingness to pay is calculated based on the mean vector of exogenous variables, which is: $E_{\varepsilon}(DAP|\alpha, \beta, \bar{z}) = [(\alpha/\sigma)/(\beta/\sigma)]\bar{z}$, where: E= is the expected value operator; α= is the vector of the coefficients of the variables in the matrix z and represent the estimate of α/σ and the coefficient associated with the variable of the amount offered by the interviewee on their willingness to pay for an improvement of the water quality is represented by β, which is an estimate of the theoretical parameter -β/σ.

The empirical probability model that makes the previous general model operational and from which the parameters to estimate the willingness to pay are recovered is the following: $P(\theta < (\alpha_0 + \alpha_1 GEN + \alpha_2 EDAD + \alpha_3 NIVEST + \alpha_4 INTFAM - \beta MONDAP)$, where: P denotes probability,

σ_i= are the respective parameters associated with the observable variables GEN, EDAD, NIVEST, INTFAM and MONFDAP, which have been defined in Table 1, while β= is the parameter associated with the variable MONFDAP.

The empirical model was run using the PROC LOGISTIC procedure of the SAS 9.0 system. The estimated results are shown in Table 3.

Table 3. Estimation of the binary discrete choice model.

Variable	Intercept	Mondap	Gen	Edad	Nivest	Intfam
Parameter	0.3002	0.00378	0.2299	-0.029	0.4013	0.0609
Standard error	(0.9496)	0.0034	0.374	0.016	0.1234	0.1125
χ^2 of Wald	0.1	0.0118	0.3768	3.2705	10.5736	0.2928
Likelihood Ratio (R)= 16.49		McFadden pseudo-R^2 = R/U = 0.0887				
Upper Bound of R (U) = 85.96						

Based on the output of the SAS 9.0 system.

As can be observed individually, the parameters associated with the sociodemographic variables age and level of study are the only statistically significant ones according to the value of χ^2. The value of McFadden pseudo-R^2 of 0.0887 is a low value for the estimated model fit. This according to McFadden (1978), who states that a value between 0.2-0.4 represents an excellent fit of a discrete choice model. However, the expected signs are correct for the variables, except for age, where it would be expected that, at an older age, there is greater awareness of the need for better water quality. The procedure for calculating the willingness to pay is shown in Table 4.

Table 4. Estimation of the willingness to pay for better water quality.

	Variable (a)	Parameter (b)	Value (c)	Mean (d)	Product (c)*(d)
1	Intercept	σ_0	0.3		0.3
2	Gen	σ_1	0.2299	0.5208	0.1197
3	Edad	σ_2	-0.029	44.8125	-1.2996
4	Nivest	σ_2	0.4013	3.2639	1.3098
5	Intfam	σ_2	0.0609	4.2153	0.2567
6	Mondap	β	0.00378		
7				$\alpha = \sum \alpha_i$	0.68669

Made based on Haab and McConnell (2002).

Finally, and in accordance with the procedure of Haab and McConnell (2002), the willingness to pay, in this case for a higher quality of drinking water provided by SAPAL in the metropolitan area of the City of León, Guanajuato, is obtained as follows: DAP= $\frac{\alpha}{\beta} = \frac{0.68669}{0.00378} = 181.7 \approx$ \$182.00. This monetary amount of \$182.00 is monthly. In this way, the WTP (in Spanish DAP) to be paid per year per household in the metropolitan area of the City of León, Guanajuato, is \$2 180.00.

Economic valuation of water quality

If the number of water intakes reported by SAPAL (2021) will be used to carry out the economic valuation so that the institution responsible for providing the public drinking water service in León, Guanajuato, obtains resources to be able to make improvements in infrastructure and all the works and incorporation of technologies necessary to provide drinking water with a better quality, the amount obtained by type of drinking water intakes is shown in Table 5.

Table 5. Economic valuation of the water quality of León, Guanajuato.

Water intakes	Number	Annual WTP ($)	Economic valuation ($)
Domestic	449 319	2 180	979 515 420
Commercial	22 753	2 180	49 601 540
Industrial	2 611	2 180	5 691 980
Charity	1 390	Not applicable	Not applicable
Total	476 073		1 034 808 940

As can be seen in the table, if the valuation is made considering the drinking water intakes reported by SAPAL (2021), the amount obtained for the willingness to pay for a better quality of drinking water is $1.034 billion pesos. This sum of resources is high, so SAPAL would have the necessary resources to guarantee an improvement in the quality of drinking water distributed for consumption by the population of the metropolitan area of the City of León, Guanajuato. However, even if drinking water users paid only once a year an amount of $182.00, the amount obtained by SAPAL would be 86 million pesos, which would also allow to SAPAL to carry out infrastructure works to improve the quality of drinking water.

When comparing the results of the research with those of other studies that have also carried out economic valuations using the contingent valuation Table 6 shows their main results.

Table 6. Examples of economic valuation using stated preferences.

Author	Place	Theme	Annual willingness to pay ($)	Economic valuation ($)
Study	Metropolitan area of León, Guanajuato	Better drinking water quality	2 180	1 034 808 940
Hernández *et al*. (2021)	León, Guanajuato	Reduction of air pollution	131.2	60 408 083
Vásquez *et al*. (2009)	Parral, Chihuahua	24-hour guaranteed drinking water[1]	101.8	Not available
Avilés *et al*. (2010)	La Paz, Baja California Sur	Valuation of the aquifer of La Paz, BCS and use of municipal water	132.76	7 591 350

[1]= the willingness to pay in Vásquez (2009) corresponds to an average of the medians of eight cases with different question formats and statistical and economic assumptions.

Vásquez *et al*. (2009), in a study on the willingness to pay for having guaranteed drinking water for consumption in the population of Parral, Chihuahua, performing several scenarios, found an average willingness to pay of $101.80 additional on the amount of payment of the payment receipt for the drinking water service of the ordinary tap. In this study, an expansion considering the water intakes or the population of the municipality of Parral, for example, is not made, so there is no global amount of the economic valuation. In the case of Avilés *et al*. (2010), by making the economic valuation of the use of municipal water that is obtained from the aquifer of La Paz, Baja California Sur, they obtain a willingness to pay of $132.76 per household.

Other comparisons allow identifying that with the use of CV, the valuation of water yielded a spectrum of estimated values expressed in US dollars in a series of compiled studies, with a minimum of $ 0.008 m^3, a maximum of $2.88 m^3 and an average of $0.594 m^3 (Aylward *et al*., 2010), all of them below the market prices that usually contain subsidies of different nature.

Conclusions

In the present research, the economic valuation of the willingness to pay for an improvement in the quality of drinking water from the aquifer of Valle de León, which is distributed to the households of the City of León and its metropolitan area by the Drinking Water and Sewerage System (SAPAL, for its acronym in Spanish) of León, Guanajuato, has been carried out. Using a linear random utility model, operationalized through the logistic regression model, which is fed with data from questionnaires applied to a sample of users of the drinking water service, it has been estimated that the willingness to pay for the improvement of the quality of drinking water was $ 182 per month, which yields an economic valuation of 1.034 billion pesos per year.

The vehicle of collection of this figure could be made as an additional amount in the payment receipt for the drinking water service. When comparing this figure with other studies, it is found that the amount of the willingness is high. However, the problem of water in terms of quantity supplied in sufficiency and quality in Valle de León is very strong in the aquifer of Valle de León, for example, the water is extracted from wells more than 100 m deep and becomes contaminated with minerals and heavy metals.

Therefore, a high figure of the willingness to pay may be a reflection that households in León Guanajuato are aware of this problem both in the short and long term, which is manifested in a willingness to pay a high monetary amount, at least for the percentage of users who answered affirmatively in the survey (65.3%). The estimated economic valuation corresponds to the consumer surplus of households consuming drinking water in León, Guanajuato and is the basis on which policy decisions must be made about the costs of construction and development of infrastructure, maintenance measures and improvement of the existing one, as well as the incorporation of technologies that allow increasing the quality of water delivered for human consumption to households in León, Guanajuato.

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