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Article

Econometric estimation of the surplus of the consumer of recreational environmental services

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Abstract

Public goods, such as forests, rivers, lakes, or dams, provide recreational services that lack market prices. This research aimed to estimate the consumer surplus proposed by the microeconomic theory to make a valuation of recreational environmental services using the individual travel cost methodology. The sample used consisted of 213 observations and was collected in four recreational sites located in the area of the La Boquilla Dam, municipality of Camargo, Chihuahua within the Conchos River basin in 2019. The method used for econometric estimation was the Poisson regression model since the number of visits to the site is a count variable. The average surplus benefit per visitor was MX$33.12 (US$1.72). The research assumed an influx of 300 000 visitors, so the value of the recreational environmental service generated by the La Boquilla Dam in the year the research was carried out (2019) would have been MX$9 936 000 (US$515 888). It is concluded that the Poisson model is the one that best fits the count data obtained through the travel cost method and that the results could be useful to guide the design of environmental policies.

Keywords:

public goods, Poisson regression, truncated dependent variable.

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Introduction

In Mexico, as a result of structural reforms, the fiscal resources that the State transferred to public institutions decreased drastically. Then, protected natural areas, national parks, and biosphere reserves, among others, lacked sufficient financial resources to operate and therefore lacked investment resources to ensure their financial sustainability.

One option for obtaining financial resources and carrying out projects that mitigate the impacts of recreational activities on the environment was the design of schemes of payment for the enjoyment of and access to recreational sites based on economic valuation studies through the methodologies of stated preferences and revealed preferences (Limaei, 2014).

The application of payment schemes would prevent public or semi-public resources from being entirely left to market forces and from suffering potential injustices, such as being excluded from the consumption of recreational services provided by bodies of water such as the La Boquilla Dam in Chihuahua, Mexico.

The region that includes the northern states, such as Coahuila and mainly Chihuahua, is characterized by the relative scarcity of water. In this way, sites such as the La Boquilla Dam, located in the basin of the Conchos River, annually attract a significant number of consumers of recreational services from the municipalities of Chihuahua, Durango, and the state of Texas, United States of America.

In this way, the development of recreational activities in the area of La Boquilla is related to the market of transport necessary for travel to that area and all the additional costs incurred by tourists to make a trip. La Boquilla Dam is a public natural space that provides recreation and leisure services. Since the landscape, recreation, and leisure provided by the site do not have a defined market, valuation is carried out indirectly through related markets (transportation, gasoline, etc.).

Therefore, if the purpose is to carry out an economic valuation of the recreational site of La Boquilla that could guide the establishment of payment schemes that help finance improvements in the recreational site, the method of revealed preferences, specifically the approach of travel costs incurred by visitors, is the most appropriate method for the study.

In this context, this research aims to estimate the surplus of the consumer of environmental services in the recreational area of the La Boquilla Dam in the tributaries of the Conchos River in the state of Chihuahua using the method of substitute markets of travel cost to make an economic valuation that allows us to estimate a total monetary flow if a charge to the consumer for access to such recreational services were implemented.

The study by En Freeman III *et al*. (2014) presents the theoretical microeconomic concepts that justify the use of measures of change in consumer welfare. It also makes a rigorous mathematical and graphic exposition of the micro-econometric apparatus in the context of environmental economics that shows how to valuate goods whose public nature does not allow the existence of a market in which it is possible to observe the signals of prices and quantities of recreational environmental services provided by natural resources, such as land, forests, waters and soils, that in general no one can be excluded from consumption.

Another study, such as that by Dixon and Pagiola (1998), reviews the concept of total economic value (TEV), for which they argue that the idea behind TEV is that any environmental good or service is composed of several attributes, some of which are concrete and easily measurable, whereas others may be more difficult to quantify. However, the total value is the sum of all these components, not just those that can be easily measured.

Authors such as Hernández *et al*. (2017) estimated the differentiated amounts for sport fishing permits in Mexico using the travel cost method. The study was carried out in the state of Baja California Sur because it was the state where the most fishing permits were granted in 2012 (90 296), especially in Los Cabos. The econometric methodology used was the estimation of the Poisson regression model and the negative binomial model.

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Blaine (2015) review develops elements that represent a cornerstone for any applied study of consumer surplus benefit. The research reviews the statistical, econometric, and objectivity problems of microeconomic theory in empirical studies. It analyzes the problem that the researcher encounters when in the collected sample, in the recreational site and face to face with visitors, there is the problem of endogenous stratification.

The analysis by Wilman and Pauls (1987) investigates the sensitivity of the estimated consumer surplus, generated by the individual travel cost method regarding the treatment of substitute sites, the treatment of time costs and whether or not it is possible to correct the bias of the estimated parameters due to the zero-truncation nature of the dependent variable (visits or trips to the recreational site).

In this sense, Edwards *et al*. (2011) estimated a count data model of recreation demand using data from a survey of birdwatchers who visited the southwest of Delaware in the United States during the annual month-long migration of horseshoe crabs/shorebirds in 2008.

Their estimates ranged from $32 to $142 dollars per trip per household or $131 to $582 dollars per season per household. These amounts are in 2008 dollars. According to the researchers, the variation was due to differences in the opportunity cost imputed to the time worked per hour since three scenarios were assumed in said research: 1) no time cost; 2) 33% of the hourly wage was imputed and 3) 100% of the hourly wage was imputed. The family size was 1.66 members and the study found that the results of the assessment were sensitive to the inclusion of covariates in the model and it was concluded that the results obtained are useful for damage assessment and cost-benefit analysis where the practice of bird watching is affected.

Materials and methods

The study was carried out at the La Boquilla dam, which is located between coordinates 27° 32’ 14.67” and 27° 30’ 56.60” north latitude and 105° 23’ 21.01” and 105° 43’ 25.26” west longitude. The dam has a height of 80 m and has a capacity of 2 894 hm^3; it was built between 1910 and 1915 (Rubio *et al*., 2014). La Boquilla has the largest body of water in Chihuahua and its approximate dimensions are three kilometers wide by eight kilometers long; it is a tourist destination of economic importance for the municipality and is the second tourist destination in the state during summer vacations. Along with a small dam called Lago Colina, these waters are used for amenities and water sports activities.

The original study for which the information used in this study was collected was conducted for the World Wide Fund for Nature (WWF) and the data used in this research were released in 2021 for academic study purposes. The number of questionnaires applied in four recreational sites located in the area of the La Boquilla Dam was 483. These sites were El Tigre, Lago Colina, Los Altos and Los Filtros; however, a subsample of 213 observations was used in this research.

The total travel cost was estimated by adding the following items: gasoline expenses, the cost of meals and lodging during the trip, if the transfer was by public transport, the cost of the ticket was quantified, the cost of renting equipment to take a boat ride, rowing, etc., and the cost of access to the recreational site located in the La Boquilla Dam.

The study used the Poisson regression model. If a random discrete variable Y follows the Poisson distribution, its probability density function is given by

$$f\left(Y\, y_i\right)=Pr\left(Y=y_i\right)=\frac{e^{-\lambda_i}\lambda_i y_i}{y_i!},\, y_i=0, 1, 2\ldots$$

Where: $f(Y\, y_i)$ denotes the probability that the discrete random variable Y will take a non-negative integer value y_i. Where: $y_i!$ implies that

$$y_i!= y*(y-1)*(y-2)*\ldots*2*1 \text{ with } 0!=1$$

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Where: λ is the parameter of the Poisson distribution.

Note that the Poisson distribution has only one parameter λ, unlike the standard normal distribution which has two parameters, the mean and the variance. A unique feature of the Poisson distribution is that the mean and variance are the same. This characteristic, which is known as equidispersion, is a restrictive feature of the Poisson distribution since, in practice, the variance of the count variables is often greater than the mean. This property is called overdispersion (Hilbe, 2014; McConell, 2002).

The Poisson regression model can be written as follows:

$$y_i=E(y_i)+u_i=\lambda_i+u_i$$

Where: the y's are independently distributed as Poisson random variables with mean λ_i for each individual that are expressed as follows:

$$\lambda_i=E(y_i|X_i)=\exp\left[\beta_1+\beta_2X2_i+...+\beta_kX_{ki}\right]=\exp(\beta X)$$

Where: exp(βX) indicates the constant; e elevated to the power of the bracketed expression, which corresponds to the multiple regression model, whose matrix notation is βX and in which the variables X are the regressors that determine the average value of the regression and therefore the value of the variance if the Poisson model is appropriate. For example, if the count variable is the number of visits to the La Boquilla Dam in Chihuahua in a given year, this number will depend on variables such as the visitor's income, price for admission to specific recreational sites, cost of travel, etc. By taking the exponential of βX, it guarantees that the mean value of the counting variable λ, will be positive (Coxe *et al*., 2019; Winkelmann, 2021).

In the estimation of the Poisson regression model, the coefficient of determination R^2 of the classical regression model is meaningless. The relevant statistic in this case is the likelihood ratio (LR). If the probability value (*p*-value) of LR is less than or equal to 0.05, then the LR is statistically significant, suggesting that all explanatory variables are collectively important in explaining the conditional mean of the dependent variable. Table 1 presents the variables used in the estimation of the Poisson regression model.

Table 1. Variables used in the estimated empirical model of travel cost.

Variable	Description	Scale	Unit	Expected sign
NTRI	Number of visits or trips to La Boquilla Dam	Discrete of count	Trips per person	Na
TTC	Total travel cost	Continuous	$/trip	Negative
INCOME	Head of household income	Continuous	$/moth	Positive
AGE	Age of the interviewee	Continuous	Years	Positive
SCHOO	Years of schooling	Ordinal	1= elementary school 2= junior high school 3= high school 4= bachelor's degree 5= postgraduate degree	Positive
GEND	Variable that describes whether the interviewee is male or female	Dichotomic	0= woman 1= man	Not determined a priori
SITCONG	Site congestion	Dichotomic	0= congested 1= uncongested	Not determined a priori
WAQUAL	Water quality	Dichotomic	0= bad 1= good	Not determined a priori
AMOUWA	Amount of water	Dichotomic	0= scarce 1= sufficient	Not determined a priori

n.a.= it does not apply because it is the dependent variable.

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As can be seen, nine variables were used in the study, where the dependent variable corresponds to the number of visits or trips to the La Boquilla Dam (NTRI), whereas the remaining eight correspond to the covariates.

Results and discussion

The descriptive statistics of the zero-truncated count variable (dependent variable) and of the three continuous variables of the study are shown in Table 2, whereas the absolute and relative frequencies of the five qualitative variables (nominal and ordinal) are those included in Table 3.

Table 2. Descriptive statistics of the continuous variables used in the research.

Variable	Mean	Standard deviation	Minimum value	Maximum value
Num. of trips	5.5	11.91	1	52
Travel cost ($)	914.29	983.81	30.00	6 500.00
Monthly income ($)	6 169.00	2 817.00	2 000.00	10 000.00
Age (years)	34	10	18	65

Table 3. Levels and frequencies of the qualitative variables of the study.

Variable	Level	Frequency	(%)
Schooling	Elementary	13	6.1
	Junio high school	37	17.4
	High school	75	35.2
	Bachelor's degree	82	38.5
	Postgraduate degree	6	2.8
Gender	Woman	48	22.5
	Man	165	77.5
Site congestion	Yes	84	39.4
	No	129	60.6
Water quality	Bad	44	20.7
	Good	154	72.3
	Does not know	15	7
	Total	213	100
Amount of water	Scarce	33	15.5
	Sufficient	180	84.5

Note that the relative frequency of a qualitative variable is interpreted as the percentage in which the respective level of the variable occurred. For example, in the case of the nominal variable of water quality (WAQUAL), where three levels were coded (bad, good, does not know) in the design of the questionnaire, so in the total sample, the number of interviewed consumers who stated that the water quality was bad was 44, which corresponds to 20.7% in the total sample of 213 interviewees (100%).

The interpretation for the other qualitative variables and their respective levels is the same. The respective interpretation in the estimated empirical statistical model for count data is made below. Now, since, as mentioned, the dependent variable takes zero-truncated count values, the Poisson regression model was run with the n-logit 5 statistical package and the model converged to its optimal values in the fourth iteration.

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Additionally, as outlined in the theoretical framework, to evaluate the total significance of the model, if the likelihood ratio (LR) is used to evaluate the overall significance of the model, it is seen that the likelihood ratio of the restricted model (the one that only contains the term constant) and the unrestricted model has the following values: $LR_{restricted}$ = -1566.10511 and $LR_{unrestricted}$ =1206.70996.

Numerically, it can be seen that the LR of the unrestricted model is higher (less negative) than the LR of the restricted model. Since the goal of maximum likelihood is to maximize the likelihood function, then the likelihood ratio of the unrestricted model is chosen; that is, the model that has all the explanatory variables is chosen, which is statistically significant. Table 4 shows the estimated parameters of the empirical econometric model.

Table 4. Estimated parameters of the Poisson model.

	Parameter	Standard error	z	Pr|z|	Intervale	
					Lower	Upper
Intercept	2.70275	0.17052	15.85	0	2.36853	3.03696
TTC (#$_0$)	-0.00078	0	-11.38	0	-0.00092	-0.00065
INCOME (#$_1$)	-0.0001	0	-8.06	0	-0.00013	-0.00008
AGE (#$_2$)	0.01146	0.00305	3.75	0.0002	0.00547	0.01744
SCHOO (#$_3$)	-0.18856	0.03458	-5.45	0	-0.25633	-0.12078
GENDER (#$_4$)	0.35074	0.07926	4.43	0	0.1954	0.50609
SITCONG (#$_5$)	-0.52675	0.06379	-8.26	0	-0.65179	-0.40172
WAQUAL (#$_6$)	0.001	0.00023	4.4	0	0.00055	0.00144
AMOUWA (#$_7$)	0.32983	0.08331	3.96	0.0001	0.16655	0.4931

All parameters are significant at 1%, based on the output of the runs with n-logit 5.

On the other hand, it can be stated that, individually, all explanatory variables are statistically different from zero because their *p*-value is less than 0.05 and the value of z >2. Now, since the Poisson model is a semilogarithmic model, the parameter that weights the variable in question is interpreted as expressing that the average value of these variables is lower, if the parameter is negative, by a certain percentage in relation to the level of comparison of that variable, which is usually the first level. For example, in the case of the variable

SCHOO, the level of comparison would be the 'elementary' level.

Nonetheless, since this ordinal variable has five levels, as can be seen in Table 1, it is difficult to interpret, so only its expected sign is referred to later. However, if the ordinal variable site congestion (SITCONG) is considered, which has been categorized with only two levels (Yes and No), then the parameter associated with this variable, (β_5), is analyzed as follows: from Table 4 we have that the value of $\hat{\beta}_5$ is -0.52675, so it is interpreted by expressing that the average value of the variable (SITCONG) is lower by 40.95% in relation to the level (category) of comparison. This percentage was calculated through the following expression:

$$100\left[e^{-\beta_5}-1\right] = 100\left[e^{-0.52675}-1\right] = 100(0.590521-1) = -40.95\%$$

The same procedure applies to the calculation and interpretation of the respective percentages for the variables of schooling, gender, water quality, and amount of water (Hilbe, 2014). Nevertheless, when performing the analysis of the expected signs in the remaining variables of the estimated empirical model, the following is obtained. An inverse relationship was found between the number of visits and the total travel cost since the estimated function is a demand function; that is, the sign of the parameter that weights the total cost of travel is the correct one as it is negative, which is in accordance with what is predicted by economic theory (Grilli *et al*., 2019).

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The relationship found between NTRI and the monthly income of the consumer of environmental services (INCOME) is an inverse relationship. However, the sign was expected to be positive. In this regard as Blaine *et al*. (2015) argue, the expected direct relationship between the number of trips and consumer income is one of the relationships most supported and substantiated by microeconomic theory. Nonetheless, in the vast majority of empirical studies on travel costs, the relationship between the number of visits and income turns out to be negative (Parsons and Myers, 2022).

This author highlights the fact that, in many empirical studies, such as those by Wilman and Pauls (1987); McKean *et al*. (2012); Voltaire *et al*. (2020), they only mention such a result, without delving into the reason for such a result or mentioning that the estimated parameter is not statistically different from zero.

The expected sign of the variable AGE was positive, as expected. In the case of the expected sign of the level of schooling, it is common sense that, the higher the level of schooling, the more likely the consumer is to make a greater number of trips; however, the expected sign turned out to be negative.

Regarding the remaining four variables, gender, site congestion, water quality and amount of water a (direct or indirect) relationship established a priori between these and the number of visits to the Dam was not expected, so it is considered that the expected signs resulting in the purely statistical estimation are correct.

As stated above, the surplus of the consumer of recreational services is calculated based on the following formula:

$$CS= -\frac{\bar{V}}{\beta_1}$$

Where: CS denotes the consumer surplus; $\bar{V}$ the average number of visits to the recreational site and β_1 is the parameter associated with the total cost variable in the estimated regression of the Poisson model (Haab and McConnell, 2002; Cameron and Trivedi, 2013; Greene, 2018; Zeileis and Jackman; 2020).

Note that the parameter $\#_1$ is negative and the end on the right side of the formula is preceded by a negative sign. In this way, the estimated consumer surplus is:

$$CS= -\frac{\bar{V}}{\beta_1}= -\frac{5.5023}{-0.00078}= 7054.3$$

If this surplus of MX $7 054.3 is expressed in dollar terms at the 2023 average exchange rate of 19.26 pesos per dollar, this surplus is US $366.1 dollars. This surplus corresponds to a sample of 213 visitors, so the average surplus for each consumer of recreational services in the sample is MX $33.12 pesos or US $1.72 dollars. This value is interpreted as the average surplus or net welfare that each visitor to the La Boquilla Dam obtains from their visit to said site.

Finally, given that the number of annual visitors for the year in which the sample was collected is unknown, since there were no official figures, it was assumed that the number of visitors per year was 300 000, then the value of the recreational environmental service that the La Boquilla Dam would generate in the state of Chihuahua would be MX $9 936 000 or US $515 888 dollars.

Regarding the discussion of results, the following is presented. The method of substitute markets for individual travel cost with which the demand function for the recreation of public natural resources is estimated is used by Kipperberg *et al*. (2019). They used the combined travel cost method with contingent valuation to assess how wind turbines affect recreational activities in their vicinity in Sweden.

The findings provide valuable information for policymakers and communities in Sweden that considered the development of wind energy and they estimated a consumer surplus in the range from MX $82.5 to MX $288.75 (US $4.28 to US $14.99) per trip. Limaei *et al*. (2014) determined

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the recreational and socioeconomic values of Masouleh Forest Park, northern Iran, using the travel cost method and found that there is a significant relationship between travel time and the number of visitors, when travel time increases the number of visitors decreases; likewise, they estimated an average willingness to pay of MX $5.00 (US $0.26) per visit to the park.

In the study by Morales *et al*. (2019), they calculated the surplus of the beach recreation consumer in Los Cabos, Baja California Sur, as a tourist destination, and estimated the recreation demand function using the Poisson econometric model; as a result, they obtained a consumer surplus of US $588.24 per day on average and US $4 941.22 per stay per visitor, with an average visitor stay of 8.4 days at the site and said work concluded that the implementation of public policies aligned with the sustainability of recreational services in the different areas will allow channeling economic benefits.

Conclusions

The Poisson regression model was applied to estimate the microeconomic concept of the surplus of the consumer of recreational environmental services based on a set of data collected in a survey in the area of the La Boquilla Dam. The model used is the appropriate one because the number of trips to the Dam is a dependent variable with zero-truncated count data and whose observed values are non-negative integers, in addition to the fact that the mean and its variance are equal since the variance is a function of the mean. However, in reality, this statistical assumption is rarely fulfilled in research, as was the case in the present study. Nevertheless, it is not the purpose of this research to interpret the estimated parameters or make statistical inferences from them, it is only interested in recovering the parameter that weights the predictor variable of total travel cost to quantify the measure of change in consumer welfare.

The estimated average consumer surplus for consumers of recreational environmental services in the La Boquilla Dam area was estimated at MX $33.12 (US $1.72). Under the assumption of 300 000 visitors per year to enjoy the recreational services provided by the water from the La Boquilla Dam, in the municipality of Camargo, Chihuahua, the economic valuation of the site was estimated at MX $9 936 000 (US $515 888).

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