Nonparametric estimation of compensatory variation of recreational service consumers in a biosphere reserve in Mexico

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ABSTRACT

Objective: This study aims to estimate and compare the compensating variation associated with recreational access to the La Michilía Biosphere Reserve, Durango, to provide robust technical evidence for its sustainable management and conservation.

Design/methodology/approach: A contingent valuation method was employed using a dichotomous referendum format (yes/no), based on a survey administered to 148 residents from neighboring communities. Willingness to pay was estimated using both non-parametric approaches (Kaplan-Meier, Kriström, and Turnbull) and a parametric logistic regression model.

Results: The average compensating variation estimated through the non-parametric Turnbull method was $41.33 per visitor, whereas the logistic model yielded an estimate of $52.30. This discrepancy highlights the conservative bias of non-parametric methods, which mitigate the risk of overestimation due to restrictive functional form assumptions.

Limitations/implications: The positive skewness in the distribution of willingness to pay particularly affects the Kriström method especially its Spearman-Karber variant by extrapolating beyond the offered price range, which may constrain its empirical validity.

Findings/conclusions: The findings demonstrate a significant economic valuation of recreational services by the local population. The estimated values support the potential implementation of access fee schemes as a viable financing mechanism, contingent upon comprehensive social and regulatory assessment.

Keywords: environmental recreational services, protected natural areas, parametric functional form, logistic regression.

INTRODUCTION

In Mexico, Protected Natural Areas (PNAs) represent a key policy instrument of the Mexican state for the conservation of ecosystems, plant and animal species, and the environmental services they provide. Currently, according to the General Law of Ecological Balance and Environmental Protection and the National Commission of Natural Protected Areas, there are 226 federally designated PNAs, of which 182 are terrestrial and 44 are marine (SEMARNAT, 1988; CONANP, 2024a). These areas are considered public goods due to their ecological, social, and cultural functions; however, they face increasing challenges related to financing, governance, and community engagement (Bezaury, 2024; Miteva *et al.*, 2019). The La Michilía Biosphere Reserve, located in the state of Durango, stands as a prominent example within the national system of protected areas. Spanning over 35,000 hectares, the reserve hosts endemic species, temperate ecosystems, and rural communities with communal, ejidal, and federal land tenure systems (Halffter, 2011). Its inclusion in international databases such as the World Database of Protected Areas (UNEP-WCMC, 2019) and its designation by UNESCO (2023) underscore its global ecological significance. Nevertheless, it faces specific challenges stemming from institutional fragmentation, pressure from economically incompatible activities, and limited coordination between local and institutional stakeholders (Brenner & Job, 2022). Although a formally published Management Program exists (CONANP, 2010), its implementation and public dissemination have been markedly limited (SEMARNAT, 2022). This situation has significantly hindered participatory planning, access to updated information, and the program's effectiveness as a guiding instrument for territorial management of the biosphere reserve. Recreational access to La Michilía remains scarce, and activities such as ecotourism, wildlife and plant observation, hiking, and interpretive walks are underdeveloped (CONANP, 2024a; México Desconocido, 2023). This limitation has been documented in previous studies on forest recreation planning in protected areas in southern Durango, which highlight the need to strengthen infrastructure and the design of recreational experiences (Pérez *et al.*, 2008). According to the Federal Rights Law, the current entrance fee for protected natural areas is $23.35 MXN per person per day (CONANP, 2024b); however, it remains unclear whether La Michilía currently applies this fee scheme. In this context, estimating the compensating variation associated with recreational access becomes a relevant tool to assess public use value and inform evidence-based management decisions (Morey & Rossmann, 2008). The aim of this study is to estimate and compare the compensating variation derived from recreational access to the La Michilía Biosphere Reserve, using both parametric and non-parametric methods to generate economic evidence that supports the valuation of the area's public use. It is important to clarify that the research does not aim to prescribe normative decisions but rather to produce empirical information that can be considered by decision-makers within their institutional mandates and policy instruments, in order to design and implement programs and projects related to the management and use of natural resources considered public goods.

MATERIALS AND METHODS

To estimate the compensating variation associated with recreational access to La Michilía, the contingent valuation method was employed using a dichotomous referendum format (yes/no). This approach followed the methodological guidelines proposed by Mitchell and Carson (1989), Arrow *et al.* (1993), Carson and Steinberg (1990), and Johnston *et al.* (2017). The latter provided key insights into experimental survey design for discrete choice preferences, thereby enhancing the structural validity of the applied format. A custom-designed questionnaire comprising 20 questions was developed specifically for this study. A pilot test was conducted in the field to refine the wording, sequence, and sensitivity of the questions prior to the final implementation. Redundant items were removed, and the phrasing of ambiguous questions was clarified. The survey was administered in 2021 to a sample of 148 individuals over the age of 18, all residing in four communities adjacent to the reserve. Although convenience sampling was employed, efforts were made to ensure the greatest possible diversity in age, gender, and occupation. Given the exploratory nature of the study and the use of convenience sampling, it is not possible to report a statistical margin of error or confidence level. However, the sample is considered to offer a useful approximation of the potential visitor profile for the biosphere reserve under study.

The variables analyzed included the hypothetical price offered (MX$20-MX$60) within the simulated market scenario presented in the questionnaire. A detailed description of the variables considered in the study is provided in Table 1.

The compensating variation for recreational access to La Michilía was estimated following the methodologies proposed by Kriström (1990), Turnbull (1976), and Haab and McConnell (2002). The estimations were conducted using R software version 4.2, specifically the "DCchoice" package, as documented by Nakatani (2025) and Aizaki *et al.* (2014). The logistic regression equation used to estimate the probability that an environmental service user accepts the offered price (PRC) is presented in Equation 1.

$$\Pr(Si) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 P + \beta_2 X_2 + ... + \beta_k X_k)}} \quad (1)$$

Table 1. Variables used in the estimation of compensating variation.

Variable	Description	Scale
PRC	Price offered to the respondent in the willingness-to-pay question	Discrete (MX$20, MX$30, MX$40, MX$50, MX$60)
RSP	Respondent's answer in the single-bounded referendum format	Dichotomous Nominal (Yes/No)
HHI	Household income	Discrete ($/month)
EDU	Educational attainment	Ordinal Categorical
AGE	Age	Discrete (years)
GEN	Gender	Dichotomous Nominal
FMS	Family size	Discrete

Source: own elaboration.

Where: Pr(*Si*) It is the probability that an individual will agree to pay a monetary amount (P) to have access to the environmental services of La Michilía; β_0 is the constant term (intercept); β_1 It is the coefficient that weights the offered price P; β_2,..., β_k are the coefficients of the additional explanatory variables (income, age, education, among others); X_2,..., X_k correspond to the interviewee's socioeconomic variables and are the basis of the natural logarithm.

Once the logistic regression model has been estimated, it is possible to retrieve the parameter (β_1) which weights the offered price and allows for the calculation of the compensating variation, or the average willingness to pay (WTP), for access to the recreational and biodiversity services of La Michilía. The analytical expression used to obtain the compensating variation or willingness to pay (WTP) indicator is presented in Equation 2.

$$WTP_{media} = \frac{\alpha + \sum_{k=1}^{m} \gamma_k \bar{X}_k}{\beta_1} \quad (2)$$

Where: α is the estimated intercept and corresponds to the respondent's base utility when all covariates are equal to zero; β_1 is the coefficient that weights the offered price in the single-bound referendum model and corresponds to the marginal sensitivity to changes in price, and its expected sign is negative; γ_k is the coefficient of the covariate k which represents the marginal impact of the covariate on the respondent's utility; $\bar{X}_k$ is the average value of the covariate k; m is the number of covariates with k=1, 2,..., m; and the summation symbol indicates the aggregation of the resulting values of the respective parameter that weights the average value of the covariate k in this case (Haneman, 1984).

The empirical estimation of the logistic regression model was conducted using the VGAM package in R, following the methodological guidelines for discrete response data analysis in contingent valuation studies as described by Hanemann and Kanninen (1999). This approach allows the modeling of acceptance probability as a function of the offered price (PRC) and socioeconomic covariates, ensuring statistical consistency in the estimation of compensating variation. Finally, regarding the methodological framework employed in this study, Bateman *et al.* (2002) provide a systematic overview of stated preference techniques and recommend the use of dichotomous formats to enhance empirical validity and minimize hypothetical bias in environmental valuation studies. This approach enables the simulation of hypothetical markets and the derivation of monetary estimates for stated preferences, including components of existence or non-use value (Carson & Hanemann, 2005).

RESULTS AND DISCUSSION

The descriptive statistics of the variables used in the study are presented in Table 2.

Table 2. Descriptive statistics of the key variables in the study.

Variable	Mean	Standard deviation	Minimum value	Maximum value
PRC	40.0	14.2	20.0	60
RSP	0.64	0.48	0.0	1
HHI	2,447.8	1,482.7	1,002	6,911
EDU	3.1	1.3	1	6
AGE	37.1	14.9	18	77
GEN	0.53	0.50	0.0	1
FMS	4.2	1.9	1.0	15

Note: The definition of the variables is given in Table 1.
Source: Prepared by the authors based on R-DCchoice runs.

Figure 1 shows the survival curve estimated for calculating the average willingness to pay (WTP) for La Michilía, based on field data. The horizontal axis displays the initial price offered to respondents regarding their willingness to pay for access to the reserve's services. The vertical axis presents the empirical survival probability, which represents the proportion of individuals willing to pay each offered amount or more. The survival function essentially represents the demand curve for access to the reserve's services; therefore, the area under this curve corresponds to the average WTP per individual for access to these services.

Table 3 presents the estimated results obtained using the Kriström method. As shown in the table, a survival probability of 1.0 indicates that 100% of respondents would be willing to access the reserve free of charge. Conversely, a survival probability of 0.5667 implies that 56.67% of respondents would be willing to pay $60 for access to the recreational and biodiversity services.

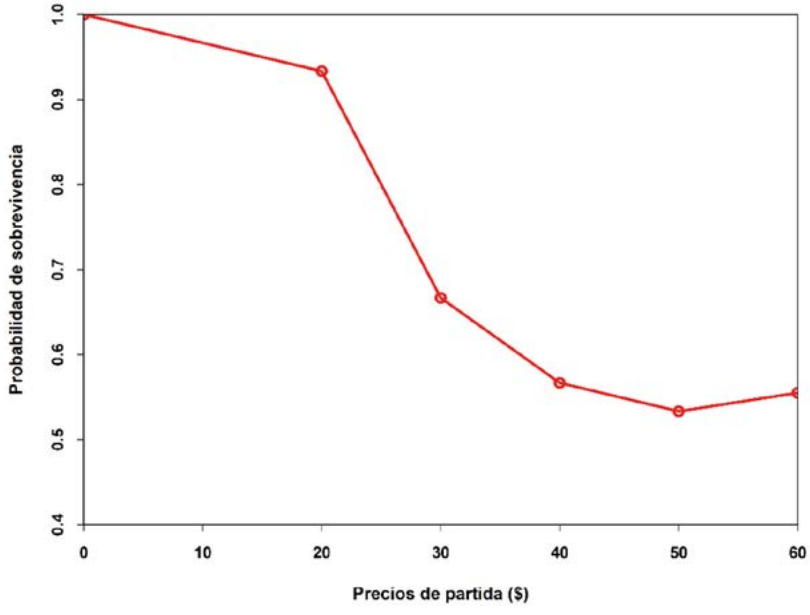

Figure 1. Kriström survival function.

Table 3. Estimated DAP and survival probability of Kristöm.

Starting price ($)	Probability of survival	Average willingness to pay (MX$/visitor)	
0	1.0000	Kaplan-Meier	41.34
20	0.9333	Spearman-Karber	81.66
30	0.6667	Median	60.00
60	0.5667		
50	0.5333		
60	0.5000		
∞	0.0000		

Note: WTP=Willingness to pay. NA=Not applicable.
Source: Prepared based on Nakatani (2023) and Kriström (1990).

Similarly, the results from the Turnbull model adjustment used to estimate the average compensating variation under a single-bounded referendum format, as well as the interpretation of its survival probability, are analogous to those of the Kriström method, as shown in Table 4. In this case, a survival probability of 1.0 indicates that 100% of respondents would be willing to enter the reserve free of charge, while a survival probability of 0.5333 indicates that 53.3% would be willing to pay $50 for access to La Michilía's services.

One way to assess the behavior of the WTP estimates obtained through non-parametric procedures is to compare them with their parametric counterpart, which assumes a specific functional form. This comparison is essential to evaluate the robustness of the estimates. The estimated parameters of the logistic regression model which models the respondent's acceptance probability as a sigmoid function of the offered prices as well as the associated test statistics, are presented in Table 5.

As can be seen, the parameter (γ_1) which weights the price offered to the interviewee (PRC) is statistically significant at 99% confidence. The parameter (γ_2) which weights family income (HHI) is significant at 95% confidence level. Both parameters are well behaved as they present the expected sign; that is, negative for γ_1 y positivo para γ_2. The parameters of the remaining covariates are not statistically significant; however, their

Table 4. Estimated WTP and survival probability of turnbull.

Starting price ($)	Probability of survival	Average willingness to pay (MX$/visitor)	
0	1.0000	Kaplan-Meier	41.33
20	0.9333	Spearman-Karber	44.17
30	0.6667	Median	55.00
60	0.5667		
50	0.5333		
60	0.5000		
∞	0.0000		

Note: WTP=Willingness to pay.
Source: Prepared based on Nakatani (2023).

Table 5. Estimated parameters of the logistic regression model.

Variable	Parameter	Standard error	z value	Pr(>|z|)
Intercept	3.2826	1.2281	2.673	0.0075 ***
PRC	−0.0591	0.0151	−3.914	0.0001 ***
HHI	0.0004	0.0002	2.032	0.0421 **
AGE	−0.0252	0.0142	−1.778	0.0754 *
EDU	0.0064	0.2059	0.031	0.9753
GEN	0.5336	0.3973	1.343	0.1792
FMS	−0.1258	0.1128	−1.115	0.2649

*** significant at the 99% level, ** significant at the 95% level, * significant at the 90% level. Note: Variable names correspond to those defined in Table 1. Source: Prepared using R-VGAM.

inclusion is common in economic valuation studies. The expected sign of these covariates was not specified *a priori*, as no economic theory dictates whether they should be positive or negative. The average willingness to pay (WTP), estimated using the logistic regression model and calculated through the expression in Equation 2 (see Materials and Methods), was $52.30 per potential user of La Michilía's services. Before proceeding with the results discussion, it is important to note that WTP values were estimated using non-parametric estimators —Kaplan-Meier and Spearman-Kärber under the Kriström and Turnbull approaches, as well as a parametric logistic model to incorporate covariates. The Kaplan-Meier estimate ($41.33) was selected for discussion due to its ability to reflect the actual range of offered prices ($0-$60), avoiding invalid extrapolations such as that of the Spearman-Kärber method ($81.66). Its consistency with both the Kriström and Turnbull approaches ($41.33) supports its reliability, while the discrepancy with the logistic regression estimate ($52.30) suggests that parametric assumptions may overestimate the compensating variation (or WTP) in this context. Although the vast majority of reviewed contingent valuation studies apply parametric approaches, Soncco and Armas (2008) compared WTP for water protection services using both parametric and non-parametric methods in the Jequetepeque River basin, Peru. Their study employed a linear logit model for the parametric approach and Turnbull and Kriström techniques for the non-parametric methods. Their results showed no significant differences between methods, and they recommend using multiple approaches in the economic valuation of ecosystem services to obtain more reliable and precise estimates, emphasizing that both approaches are complementary.

Cerda and Vásquez (2005) applied contingent valuation to estimate WTP for water use from the Claro River in Talca, Chile, using both parametric and non-parametric approaches. Their results show a similar pattern to those of the present study, with parametric WTP values approximately 20% higher than their non-parametric counterparts. This corroborates the tendency of parametric methods to yield higher WTP estimates due to the imposition of a smooth, symmetric functional form on the data. Moreover, the inclusion of covariates that increase the probability of payment tends to extrapolate higher values than those strictly observed in the empirical data unlike more conservative non-parametric methods. As illustrated, the use of non-parametric

methods responds to the need for prudent estimates, especially when compared to parametric models, and better alignment with observed behavior within the offered price range. Their conservative nature helps avoid overestimations stemming from restrictive functional assumptions, which is particularly relevant in contexts where pricing sensitivity must be evaluated with caution. An important point to underscore is that, like all research on compensating variation, this study faces methodological limitations. Hypothetical bias persists due to the simulated payment scenarios, even though the referendum format recommended by Arrow *et al.* (1993) which tends to reduce such bias was applied. External validity is limited by the sample size and scope (148 respondents from communities near La Michilía). Moreover, while non-parametric methods are conservative, they can be affected by positive skewness in the WTP distribution. For instance, the Spearman-Kärber variant extrapolates beyond the offered range. These limitations do not invalidate the results but do constrain their applicability to public policy design concerning natural resource management.

CONCLUSIONS

This study concludes that local residents in the region surrounding the La Michilía Biosphere Reserve recognize and value the recreational and ecosystem services provided by this protected natural area. This is evidenced by their willingness to pay a monetary fee to enjoy its recreational, environmental, and ecosystem benefits. The application of the Kaplan-Meier method yielded a robust and consistent estimate of the average willingness to pay, set at $41.33 per visitor, a value aligned with both the Kriström and Turnbull approaches. This result supports the hypothesis that there is a positive economic valuation among nearby municipalities for recreational access to the reserve. The evidence suggests that implementing a recreational access fee could be a viable strategy to strengthen the reserve's financing and management, contributing to both natural resource conservation and the well-being of local communities. Ultimately, the findings of this study provide relevant information for decision-making processes aimed at economic diversification and the formulation of public policies that promote the sustainable use and effective governance of protected natural areas like La Michilía. This research is framed within a strictly academic context, with the primary objective of generating technical evidence on the economic valuation of ecosystem services. It does not intend to issue normative or operational recommendations. While the results may inform public decisions, the study does not explicitly propose the implementation of a fee system. In complex contexts such as that of La Michilía, it is up to the competent authorities and local stakeholders to deliberate on the feasibility of any access scheme, considering the results of this study as a technical input.

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