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# Dichotomous contingent valuation of the water ecosystem service in an Andean micro-watershed in Ecuador

## Valoración contingente dicotómica del servicio ecosistémico hídrico en una microcuenca andina del Ecuador

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**Abstract**

The moorland or paramo is a threatened ecosystem. The indiscriminate advance of the agricultural frontier is producing the loss of ecosystem services, especially water service. This research estimated the willingness to pay (WTP) of the water users corresponding to the Municipality of Riobamba for the conservation of the water service in the Micro-basin of the Chimborazo River (MCRCH). Four hundred and six surveys were applied by means of the double limit dichotomous contingent valuation method, using a maximum likelihood model in the Stata software. Four models were developed: simple limit, simple limit with other explanatory variables, double limit, and double limit with other explanatory variables, the latter being statistically more significant. As a result, it was determined that the WTP is USD 0.84 per month to conserve the water service of the MCRCH, value that increases if the home ownership variable is included in USD 0.04. The problem of climate change increases in USD 0.24, while the variable level of education decreases the WTP by USD 0.04.

***Keywords***: Contingent valuation, Dichotomous model, paramo or moorland, water Economy.

**Resumen**

El páramo es un ecosistema amenazado pues el avance indiscriminado de la frontera agrícola está produciendo la pérdida de servicios ecosistémicos, especialmente del servicio hídrico. Esta investigación estimó la disposición a pagar (DAP) de los usuarios de agua del Municipio de Riobamba, por la conservación del servicio hídrico de la Microcuenca del Río Chimborazo (MCRCH). Se aplicaron 406 encuestas, mediante el método de valoración contingente dicotómico de doble límite, usando un modelo de máxima verosimilitud en el software Stata. Se desarrollaron cuatro modelos de simple límite, de simple límite con otras variables explicativas, de doble límite y de doble límite con otras variables explicativas, siendo este último estadísticamente más significativo. Como resultado se determinó que la DAP es de USD 0,84 mensuales para conservar el servicio hídrico de la MCRCH, valor que se incrementa si se incluye la variable vivienda propia en USD 0,04 y al reconocer el problema del cambio climático en USD 0,24, mientras que la variable nivel de educación disminuye la DAP en USD 0,04.

***Palabras clave***: Valoración contingente, Modelo dicotómico, páramo, economía del agua.

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# 1 Introduction

The moorland in Ecuador holds significant ecological and economic importance (Hofstede et al., 2002). Millions of people depend directly or indirectly on its conservation. It is one of the most threatened ecosystems due to the expansion of agricultural areas, poor livestock management practices—including burning and overgrazing—the introduction of exotic species, mining, and hunting. These activities have transformed this fragile yet rich continuous landscape of peatlands, shrubs, and giant rosettes into a fragmented and degraded grassland ecosystem (Vuille et al., 2008).

A useful tool for highlighting the importance of an ecosystem is economic valuation, which translates changes in human well-being into monetary units based on variations in the quality or quantity of ecosystem goods and services. Economic valuation thus allows the quantification of the value of ecosystem goods and services in monetary terms, regardless of whether or not they have a price or market (Ministry of the Environment, 2015).

Environmental economic valuation is supported by a solid conceptual framework grounded in two branches of economic theory: microeconomics and welfare economics. In the first case, consumer preference theory is employed. In the second, monetary measures of well-being are derived and analyzed, as assessing the value of ecosystem goods and services requires linking them to changes in individual well-being (Ministry of the Environment, 2015). This type of valuation not only provides insights into their economic contribution but also determines whether people accept such investments and are willing to pay for the benefits obtained. Another decision-making approach for assessing the economic value of water involves evaluating non-structural or policy alternatives (Perez, 2010). Several studies on the economic valuation of water have been conducted worldwide in recent years, which are summarized in Table 1.

**Table 1.** Economic valuation studies of water worldwide in recent years.

| Continent | Study | Author | WTP (USD) |
|---|---|---|---|
| America | Water springs under the direction of the local municipality of the city of Flagstaff. | Mueller (2014) | 4.89 |
| America | Application of the travel cost and contingent valuation methods to determine the willingness to pay for the conservation of water resources in Cajas National Park in the city of Cuenca. | Armijos Espinosa and Segarra Ortega (2016) | 1.04 |
| America | Contingent valuation in protected areas: The case of the Amazon sector, Ecuador. | Córdova et al. (2019) | 5.15 |
| America | Economic value of water from the Solís dam, located in Acámbaro, Guanajuato, Mexico. | Trujillo and Perales (2020) | 1 |
| Asia | Application of the contingent valuation method for a case study in Ramallah Governorate, Palestine, including urban, rural and refugee camps. | Awad and Holländer (2010) | 189.37 |
| Asia | Contingent valuation method using a simple dichotomous boundary model to measure average willingness to pay that seeks to raise funds to improve the water quality of the Swat River in Pakistan. | Shah (2013) | 0.20 |
| Asia | The willingness of farmers to pay to improve the water quality of the Aksu River in Kahramanmaras province. | Ikıkat (2020) | 8.03 |

| | | | |
|---|---|---|---|
| Africa | Applying a simple dichotomous boundary method to households in the Emuhaya district of Kenya. | Emily et al. (2013) | 1.10 |
| Africa | Assessment of household willingness to pay for a fluoride-safe water service connection in the Rift Valley region of Ethiopia. | Reta and Lee (2020) | 6.84 |
| Africa | Assessment of farmer households' willingness for better use of irrigation water in Southern Ethiopia. | Aman et al. (2020) | 13.92 |
| Africa | Determination of households' willingness to pay for improved operation and maintenance services in eight gravity-fed water systems on the island of Idjwi in the Democratic Republic of Congo. | Jimenez et al. (2021) | 0.16 |
| Africa | Use of the contingent valuation method to assess consumers' willingness to pay for improved continuous municipal water supply service in Chitungwiza. | Zvobgo (2021) | 40 |
| Africa | Analysis of the willingness to pay and participate in volunteer activities for the restoration of the Sosiani River in Eldoret, Kenya. | Wambui and Watanabe (2021) | 1.54 |

Consequently, there is global information available on the contingent valuation method (CVM). Unfortunately, such studies are scarce in Ecuador, particularly those using double-bounded dichotomous models. Hanemann (1991) propose an alternative to improve the efficiency of estimations in dichotomous contingent valuations. This alternative is known as the double-bounded dichotomous choice method. In this approach, following the initial dichotomous contingent valuation question, a second follow-up question is asked. Specifically, if the respondent answers "yes" to the first question, they are asked about a higher amount. Conversely, if they answer "no" to the first question, they are offered a lower amount. This implies that the second question is endogenous, as it depends on the response to the first question, which is exogenous.

With this method, two responses are obtained from everyone, providing more information but simultaneously complicating the econometric analysis.

Given that $y_i^1$ and $y_i^2$ represent the responses to the first and second questions, respectively, the probability that an individual answers "Yes" to the first question and "No" to the second can be expressed as: $\Pr(y_i^1 = 1, y_i^2 = 0 \mid z_i) = \Pr(\text{Sí}, No)$, with similar expressions for the other three possible combinations. Assuming the function $WTP_i(z_i, u_i) = z_i\beta + u_i$ y $u_i \sim N(0, \sigma^2)$,, the likelihood of each case occurring is given by:

- Case 1: $y_i^1 = 1,\ y_i^2 = 0$

$$\begin{aligned}\Pr(\text{Yes}, No) &= \Pr(t^1 \leq WTP < t^2)\\ &= \Pr(t^1 \leq z_i{}'\beta + u_i < t^2)\\ &= \Pr\left(\frac{t^1 - z_i{}'\beta}{\sigma} \leq \frac{u_i}{\sigma} < \frac{t^2 - z_i{}'\beta}{\sigma}\right)\\ &= \Phi\left(\frac{t^2 - z_i{}'\beta}{\sigma} \leq \frac{u_i}{\sigma} < \frac{t^1 - z_i{}'\beta}{\sigma}\right)\end{aligned}$$

The last equality is obtained by using $\Pr(a \leq X < b) = F(b) - F(a)$, Therefore, using the symmetry property, we have that:

$$\Pr(\text{Yes}, No) = \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) - \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right)$$

- Case 2: $y_i^1 = 1,\ y_i^2 = 1$

$$\begin{aligned}\Pr(\text{Yes}, \text{Yes}) &= \Pr(WTP > t^1, WTP \geq t^2)\\ &\Pr(z_i{}'\beta + u_i > t^1, z_i{}'\beta + u_i \geq t^2)\end{aligned}$$

Applying Bayes' rule, $\Pr(A,B) = \Pr(a \mid b) \times \Pr(B)$ it is held that:

$$\Pr(\text{Yes},\text{Yes}) = \Pr(z_i{}'\beta + u_i > t^1 \mid z_i{}'\beta + u_i \geq t^2) \times \Pr(z_i{}'\beta + u_i \geq t^2)$$

Since $t^2 > t^1$ and therefore $\Pr(z_i{}'\beta + u_i > t^1 \mid z_i{}'\beta + u_i \geq t^2) = 1$ then:

$$\begin{aligned}\Pr(\text{Yes},\text{Yes}) &= \Pr(u_i \geq t^2 - z_i{}'\beta) \\ &= 1 - \Phi\left(\frac{t^2 - z_i{}'\beta}{\sigma}\right)\end{aligned}$$

By symmetry:

$$\Pr(\text{Yes},\text{Yes}) = \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right)$$

- Case 3: $y_i^1 = 0,\ y_i^2 = 1$

$$\begin{aligned}\Pr(\text{No},\text{Yes}) &= \Pr(t^2 \leq WTP < t^1) \\ &= \Pr(t^2 \leq z_i{}'\beta + u_i > t^1) \\ &= \Pr\left(\frac{t^2 - z_i{}'\beta}{\sigma} \leq \frac{u_i}{\sigma} < \frac{t^1 - z_i{}'\beta}{\sigma}\right) \\ &= \Phi\left(\frac{t^1 - z_i{}'\beta}{\sigma} - \Phi\frac{t^2 - z_i{}'\beta}{\sigma}\right) \\ \Pr(\text{No},\text{Yes}) &= \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) - \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right)\end{aligned}$$

- Case 4: $y_i^1 = 0,\ y_i^2 = 0$

$$\begin{aligned}\Pr(\text{No},\text{No}) &= \Pr(WTP < t^1, WTP < t^2) \\ &= \Pr(z_i{}'\beta + u_i < t^1,\ z_i{}'\beta + u_i < t^2) \\ &= \Pr(z_i{}'\beta + u_i < t^2) \\ &= \Phi\left(\frac{t^2 - z_i{}'\beta}{\sigma}\right) \\ \Pr(\text{No},\text{No}) &= 1 - \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right)\end{aligned}$$

Thus, the Lopez-Feldman (2012) model would depend on four conditional equations:

$$\Pr(y_i^1, y_i^2 \mid z_i) = \begin{cases} \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) - \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) & \text{si } y_i^1 = 1, y_i^2 = 0 \\ \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) & \text{si } y_i^1 = 1, y_i^2 = 1 \\ \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) - \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^1}{\sigma}\right) & \text{si } y_i^1 = 0, y_i^2 = 1 \\ 1 - \Phi\left(z_i{}'\frac{\beta}{\sigma} - \frac{t^2}{\sigma}\right) & \text{si } y_i^1 = 0, y_i^2 = 0 \end{cases}$$

The single-bounded dichotomous contingent valuation method can be estimated using the Probit model, a type of econometric model for binary choice— a choice between two options. This model is characterized by its reliance on the standard normal cumulative distribution. In contrast, the results for double-bounded dichotomous contingent valuation are obtained through the maximum likelihood method, which directly estimates the β coefficients used to calculate the mean willingness to pay (WTP). The doubleb command in Stata facilitates the analysis process (Lopez-Feldman, 2012).

For analyzing explanatory variables, the *stepwise* command can be used, which controls statistical criteria in stepwise procedures to build a model. This subcommand is ignored if no stepwise method is specified. It supports regression models where the selection of predictive variables is conducted through an automated process. This procedure involves a sequence of F-tests to select or remove explanatory variables (Lopez-Feldman, 2012).

The main objective of this study is to determine the economic cost, expressed in monetary terms, that the population assigns to the water service provided by the Chimborazo River Micro-basin (MCRCH) under current conditions, i.e., a real-world scenario. Respondents were given only the necessary information to descriptively introduce the valuation context. They were informed that the water reaching their homes originates from the MCRCH, thus explaining the implementation framework of the survey.

The hypothetical nature of the stated preference method assumes no real payment commitments from respondents, which often leads to exaggerated individual WTP estimates (Kjær, 2005). Cummings and Taylor (1999) suggest that this bias can be mitigated through a simple explanation provided before the question, highlighting the risks associated with exaggerated responses, particularly regarding WTP and income-related questions.

The sustainability of the moorland ecosystem, approached from a welfare economics perspective for natural resource conservation, offers an alternative framework. It evaluates the economic value of water, emphasizing the idea that conserving natural resources ensures true sustainable development.

Accordingly, this study conducted the economic valuation of the water service using a stated preference methodology-contingent valuation.

## 2 Materials and Methods

The study population consists of 32,739 urban households in the city of Riobamba, whose water consumption is primarily supplied by groundwater from the Chimborazo River Micro-basin (MCRCH). This population is classified as domestic consumers of the Public Water Company (EMAPAR). According to the 2020 database, EMAPAR had a total of 37,251 registered users, including all categories (residential, commercial, industrial, and others) (EMAPAR, 2020). For the purposes of this study, only the residential consumption category, which accounted for 90 % of the total, was considered. The other categories were excluded as they do not represent end users. In this context, water consumption meters were treated as the sampling units.

The survey was conducted using Google Forms by sending emails to registered potable water users. Respondents were distributed into four groups according to their respective urban parishes, as shown in Figure 1 (Group 1 = Lizarzaburu Parish, Group 2 = Maldonado Parish, Group 3 = Veloz Parish, and Group 4 = Velasco and Yaruquíes Parishes). The selected variant of the Contingent Valuation Method (CVM) aimed to determine the maximum WTP of consumers through a double-bounded dichotomous question format.

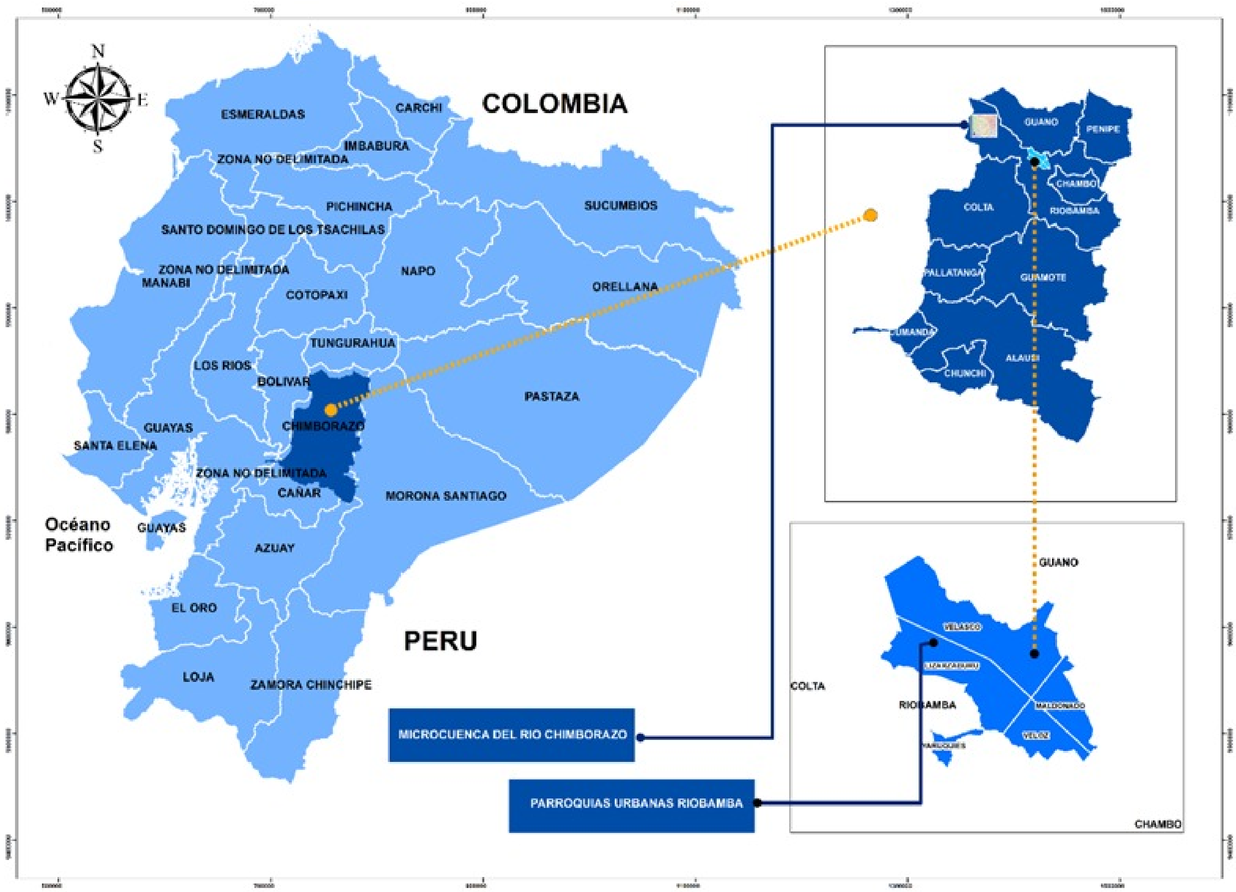


**Figure 1.** Chimborazo River micro-watershed - Riobamba urban parishes.

The first question asked: "*Would you be willing to pay an additional nn USD on your water bill to ensure the provision of water resources from the páramos of the Chimborazo River Micro-basin?*" The *nn* value was randomly selected from a vector of six values (USD 0.10, 0.25, 0.50, 0.75, 1.00, 1.25) and distributed evenly across the four groups, excluding the extreme values at both ends of the vector. Subsequently, a follow-up question presented the same inquiry with a second bid from the same vector, set as either the next higher or next lower value depending on whether the first response was positive or negative, respectively. A third, open-ended question related to the COVID-19 pandemic was included to verify the consistency of the responses. Since this question was endogenous to the previous ones, it did not affect the earlier results. The survey recognized respondents' monthly water consumption payment receipts as general evidence of their participation.

A pilot survey involving 40 participants was conducted to improve the clarity of certain questions, reduce their number due to time constraints, and make necessary adjustments to the bid vector. According to Sueki (2013), approximately 400 participants are required for a CVM with double-bounded dichotomous questions to minimize estimation errors and achieve statistically reliable WTP conclusions. Similarly, Alam (2013) established a sample size of 400 for a water-related CVM study, while Tentes and Damigos (2012) described their research with 310 cases.

For this study, formula (2) was used, where dichotomous responses provided a satisfactory approximation (Cochran, 1983). Considering the given conditions, p corresponded to an unbiased estimate of p, and the sample size was determined as follows:

$$N = \frac{no}{1} + \frac{no}{N} \tag{1}$$

So that,

$$no = \frac{z2\ p(1-p)}{e2} \tag{2}$$

Considering the population as $N$=32,739 water connection points for human consumption, a 95% confidence level ($z$=1.96), an acceptable margin of error ($e$=5%), and a 50% probability of approving the bid ($p$=50%), the required sample size was calculated to be 380 cases. This sample size was expanded to 406 respondents. For selecting the sampling elements, the option for managing complex models was utilized, applying a simple random sampling method followed by a homogeneous distribution across four groups from different sectors of the city, resulting in responses from 406 individuals.

The survey was structured into five sections, each including questions related to a specific topic, as follows:

- About Water
- About the Environment and Climate Change
- Willingness to Pay (WTP)
- Use of Public Resources
- Socioeconomic Information

This methodology enabled the development of four models (calculations included in the Stata software annex). Respondents were not informed they would be asked twice about their WTP. Therefore, the response to the first bid was exogenous to the second, allowing WTP estimation as if it were a single-bounded dichotomous question survey. For this case, the Probit model with a single explanatory variable (simple model, Model A) was used.

Model Descriptions:

Model A: Similar to a single-bounded dichotomous approach, this model excluded the second bid and included only one explanatory variable. The Probit model was used to estimate the WTP.

Model B: As in Model A, the second bid was not included, but all explanatory variables were considered. Using the stepwise command, only statistically significant variables were selected, and the Probit model was applied to determine WTP.

Model C: This model applied the maximum likelihood estimation method using the doubleb command. Only variables corresponding to the two bids and their respective responses were included, without considering additional explanatory variables. WTP was determined accordingly.

Model D: Statistically significant variables were selected using the stepwise command. Like Model

C, the maximum likelihood method was used with the doubleb command to determine WTP.

## 3 Results and Discussion

Before estimating the WTP using a CVM, various characteristics of the population were analyzed. It was determined that in the Riobamba canton, 96% of users have a direct connection to the drinking water network, 95% report receiving water service daily, 63% have a cistern for water storage, and 54% believe that the distribution issues stem from an inefficient drinking water network.

Regarding solutions to these issues and monthly water payments, 72% of respondents feel that the Municipality of Riobamba, through EMAPAR, does not make effective decisions to address water scarcity problems. Additionally, 30% reported paying more than USD 20 per month for drinking water service.

The average income of the surveyed group is USD 641.63, and the cost of drinking water per cubic meter is USD 0.49.

**Simple limit (first offer only) with no other explanatory variables**

**Table 2.** Simple Boundary Model A

| WTP01 | Coef. | Std. Err. | z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|
| PRE1 | -1.17 | 0.24 | -4.81 | 0.00 | -1.65 | -0.70 |
| Cons | 1.31 | 0.18 | 7.15 | 0.00 | 0.95 | 1.67 |

With:
WTP01=Dichotomous response to first offer (explained variable).
PRE1=first offer (explanatory variable).
coef=constant value.

According to the total of PRE1 (-1.17), it can be observed that an increase in the offer leads to a lower probability of acceptance by the respondent.

**Table 3.** Simple boundary WTP Model A

| WTP01 | Coef. | Std. Err. | z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|
| WTP | 1.12 | 0.10 | 10.80 | 0.00 | 0.92 | 1.32 |

Based on the results shown in Table 2, the maximum WTP of USD 1.12 is obtained (Table 3), corresponding to the value from Model A, which is statistically significant. The estimation is based on a 95% confidence level.

**Model B: Simple limit (first offer only) with other explanatory variables**

**Table 4.** Simple Boundary Model B with other explanatory variables

| WTP01 | Coef. | Std. Err. | Z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|
| PRE1 | -1.19 | 0.25 | -4.80 | 0.00 | -1.67 | -0.70 |
| SE06 | -0.10 | 0.06 | -1.75 | 0.08 | -0.21 | 0.01 |
| ACC04 | 0.40 | 0.18 | 2.20 | 0.03 | 0.04 | 0.76 |
| SE07 | 0.10 | 0.05 | 1.94 | 0.05 | 0.00 | 0.19 |
| Cons | 1.11 | 0.31 | 3.55 | 0.00 | 0.49 | 1.73 |

For the analysis in Table 4, the following variable descriptions are important to consider:
PRE1: Value of the first bid.
SE06: Education level (Primary, Secondary, University, Master's, Doctorate).
ACC04: Climate change issue (Dichotomous).
SE07: Housing condition (Owned, Rented, Family-owned, Mortgaged).

These coefficients allowed for inferring the likelihood that a respondent would accept the first bid. Variables with positive coefficients increase this likelihood, while those with negative coefficients decrease it. However, in this study, this model serves as an intermediate step for estimating the average WTP.

**Table 5.** Simple Boundary Model B WTP

| WTP01 | Coef. | Std. Err. | z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|
| WTP | 1.13 | 0.10 | 10.74 | 0.00 | 0.92 | 1.33 |

It should be noted that if the respondent is aware of the climate change issue, their WTP increases by USD 0.40. Similarly, their housing condition raises the WTP by USD 0.09. However, education level, a variable with a negative coefficient, decreases the WTP by USD 0.09 (Table 4). In Model B, the estimated WTP is USD 1.13 (Table 5).

**Model C: double-bounded dichotomous method (two bids) with no other explanatory variables.**

**Table 6.** Double Boundary WTP Model C

| | | Coef. | Std. Err. | Z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|---|
| Beta | cons | 0.84 | 0.03 | 30.05 | 0.00 | 0.78 | 0.89 |
| Sigma | cons | 0.50 | 0.03 | 17.23 | 0.00 | 0.44 | 0.55 |

Using the maximum likelihood model and the doubleb command, the average WTP is estimated at USD 0.84 for Model C, which, according to the analysis conducted in Stata, corresponds to the beta constant (Table 6). This value is lower than the results obtained in the two previous models.

### Model D: double-bounded dichotomous method with other explanatory variables

**Table 7.** Double Boundary Model D

| | | Coef. | Std. Err. | z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|---|
| *Beta* | SE06 | -0.04 | 0.02 | -1.83 | 0.07 | -0.08 | 0 |
| | SE07 | 0.04 | 0.02 | 1.92 | 0.06 | 0 | 0.08 |
| | ACC04 | 0.24 | 0.08 | 3.13 | 0 | 0.09 | 0.39 |
| | cons | 0.68 | 0.11 | 6.47 | 0 | 0.48 | 0.89 |
| *Sigma* | cons | 0.49 | 0.02 | 17.26 | 0 | 0.43 | 0.54 |

**Table 8.** Double Boundary D Model WTP

| | Coef. | Std. Err. | Z | P>z | [95% Coef. Interval] | |
|---|---|---|---|---|---|---|
| Beta | 0.84 | 0.03 | 30.42 | 0.00 | 0.78 | 0.89 |

It should be noted that homeownership increases the WTP by USD 0.04, and awareness of climate change issues raises it by USD 0.24. Conversely, variables with negative coefficients, such as education level, decrease the WTP by USD 0.04 (Table 7). The average WTP in Model D is USD 0.84 (Table 8).

Hanemann (1991), argue that using a CVM with single-bounded dichotomous questions is easier for respondents but is statistically less efficient than a double-bounded method, as it requires larger sample sizes to achieve a certain level of precision. The results generated by the four models provide a basis for identifying the most statistically significant WTP. Hanemann (1991) emphasize that the best models prioritize the impact on achieved precision, reflected in narrower confidence intervals. This aligns with Kjær (2005), who states that more precise estimates are associated with smaller confidence intervals and, consequently, greater statistical efficiency.

In agreement with the findings of Hanemann (1991) and Kjær (2005) regarding the precision achieved in confidence intervals and a lower standard error (Table 9), we can conclude that Model D is the most suitable for determining the maximum average WTP for the studied sample, which is USD 0.84 per month. It is worth highlighting that WTP values tend to be lower in double-bounded models. This phenomenon—where WTP decreases when information from the second question is introduced—is frequently observed (Lopez-Feldman, 2012).

**Table 9.** Statistics of the different models.

| Model | WTP USD | Std. Err. | Z | P>\|z\| | [95% Intervalo de Conf.] | |
|---|---|---|---|---|---|---|
| **A** | 1.12 | 0.10 | 10.8 | 0.00 | 0.92 | 1.32 |
| **B** | 1.13 | 0.10 | 10.74 | 0.00 | 0.92 | 1.33 |
| **C** | 0.84 | 0.03 | 30.05 | 0.00 | 0.78 | 0.89 |
| **D** | 0.84 | 0.03 | 30.42 | 0.00 | 0.78 | 0.89 |

In Ecuador, studies on dichotomous contingent valuation are scarce. Roldán (2017) conducted an economic evaluation of water resources for human consumption in the case of Cajas National Park in Ecuador, within the Tomebamba River Basin. The results established a monthly WTP of USD 3.44 using a double-bounded dichotomous question format. This value is higher than those determined in this research under Models C and D. It is important to consider that the economy of Azuay Province is stronger than that of Chimborazo Province, and the bid vectors used in Roldan's study were higher due to Azuay's greater environmental and economic awareness.

In Latin America, studies provide useful benchmarks for analysis, as these countries have developing economies and comparable ecosystems. Loyola Gonzales (2007) analyzed the WTP of families in the city of Arequipa, Peru, for the conservation of a protected mountainous area in the Andes, specifically the upper basin of the Chili River. The results showed a WTP of USD 1.41 per month using a single-bounded dichotomous question format. This value is 19.86 % higher than the estimates from Models A and B in this research, making it the most comparable study. It is undeniable that Peru's economy surpasses Ecuador's, with a GDP of USD 223,249 million for Peru and USD 106,165 million for Ecuador in 2021 (World Bank, 2021).

Avilés-Polanco et al. (2010) evaluated the hydrological service of the La Paz aquifer in Baja California, Mexico, using a double-bounded dichotomous question format. The average WTP per household was approximately USD 8.20 per month. Similarly, an economic evaluation of the water environmental services provided by the Río Pancho Poza Natural Area in Mexico, using a double-bounded dichotomous question format, yielded a WTP of USD 7.60 (Sánchez Bocarando, 2020). Both values exceed the estimates from Models C and D in this research. Mexico's GDP stands at USD 1,293,037 million (World Bank, 2021).

The USD 0.84 that individuals are willing to pay for the conservation of the MCRCH water service represents 0.13 % of the average income of respondents and a 4.2 % increase in their monthly water bill, assuming that over 30 % already pay more than USD 20 per month for water consumption. Charging USD 0.84 per month to potable water service users could generate a monthly budget of USD 27,500.76. According to Ecuador's Constitution, this budget could be managed by the Honorable Provincial Government of Chimborazo, which holds environmental jurisdiction. This fund could support socio-economic and productive programs as compensation for moorland landowners and for conservation, protection, restoration, afforestation, and reforestation efforts.

Lopez-Feldman (2012), recommends that when WTP estimates are used in cost-benefit analyses, the project's budget must be carefully assessed. For the conservation of the MCRCH, which requires an estimated USD 3,323,371.50 (Gobierno Autónomo Descentralizado de la Provincia de Chimborazo, 2019), Model B could be used as it generates the highest revenue for conservation compared to Model D, which produces a lower estimate. This reflects the difficulty in determining which set of estimates is more reliable (Lopez-Feldman, 2012).

In Europe, Söderberg and Barton (2013) detailed the results of a contingent valuation study aimed at improving recreational water quality in eutrophic lakes in southwestern Norway. The author concluded that WTP data for water quality could serve as a qualitative political indicator to support user-financed water quality measures rather than as a cardinal measure of marginal utility.

# 4 Conclusions

It is important to note that the WTP estimates obtained from Models C and D are lower compared to those from Models A and B. This phenomenon—where the average willingness to pay decreases, when information from the second question is introduced—is frequently observed. Determining which set of estimates is more reliable is challenging. On the one hand, estimates obtained using the follow-up model are expected to be more efficient; however, this does not rule out potential biases in the estimation process. The explanatory variables education level, climate change concerns, and housing conditions are significant in Models B and D.

The municipal company EMAPAR is responsible for water management in the city of Riobamba, which benefits from water sourced from the MCRCH. This study calculated the average WTP of households for the conservation of water services by developing four models. The first two models (A, B) used the single-bounded dichotomous method, focusing only on the first bid, either without (A) or with (B) explanatory variables. The latter two models (C, D) employed the double-bounded dichotomous method (two bids), also either without (C) or with (D) explanatory variables. Based on confidence intervals, Model D is the most robust and includes significant variables such as education level, housing conditions, and climate change concerns, estimating a WTP of USD 0.84 per month.

The contingent valuation analysis is being conducted as part of a cost–benefit analysis. Therefore, the various WTP estimates obtained can be used for sensitivity analysis. Model D yielded an annual economic value for the target population of USD 330,009.12 using the WTP estimate derived from the double-bounded dichotomous method with explanatory variables. On the other hand, using the information from Model B, which employs the single-bounded dichotomous method with explanatory variables, the annual economic value was USD 443,940.84.

To complete the sensitivity analysis, the conservation cost for the MCRCH is estimated at USD 3,323,371.50. In this case, regardless of which WTP version is used, the project will have a negative net economic benefit. Therefore, alternative funding sources will need to be sought to support the conservation of the ecosystem.

## Authors' contribution

E.F.C.C.: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, writing - original draft. L.A.J.D.: Supervision, validation, visualization, writing- review and editing.

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# Appendix

## A Programming and estimating models and willingness to pay in STATA

```
// Contingent valuation double-limit dichotomous
method  //
// Distribution of the Initial Offer Amount
tabulate PRE1

// Fraction of respondents who answered YES to
the VC question //
tabulate DPA01

// Sensitivity to offers //
tabulate DPA01 PRE1, column nofreq

/// 1. // DAP estimation - without covariates //
probit DPA01 PRE1

// Calculation of the Willingness to Pay //
nlcom (DAP:- _b[_cons]/_b[PRE1]), noheader

// 2. // DAP estimation - with variables
probit DPA01 PRE1 AG01 AG07 AG11 ACC03 ACC04
ACC08 SE01 SE02 SE04 SE05 SE06 SE07 SE09 SE10
SE11

// Estimation of variables
probit DPA01 PRE1 SE06 SE07

// Estimation of variables
probit DPA01 PRE1 SE10 SE11

// Estimation of variables
probit DPA01 PRE1 AG01 AG07

// Estimation of variables
probit DPA01 PRE1 SE01 SE02

// Estimation of variables
probit DPA01 PRE1 SE01 SE02 SE06 SE11

// Estimation of variables
probit DPA01 PRE1 SE06 SE09

// Estimation of variables
probit DPA01 PRE1 SE06 SE10

// Estimation of variables
probit DPA01 PRE1 SE06 SE07

// After the analysis we remove the
non-significant figures and find the
willingness to pay//

// I get the means and generate a scalar for each
explanatory variable//

summarize SE06, meanonly
scalar SE06_M = r(mean)
summarize SE07, meanonly
scalar SE07_M = r(mean)

// We find the willingness to pay //

nlcom (DAP:- (_b[_cons]+SE06_M*_b[SE06]+SE07_M*_b[SE07])
/_b[PRE1]), noheader

//////////////////////////////
*---HAROLD - OTHER SPECIFICATION

stepwise, pr(.1): probit DPA01 PRE1 AG01 AG07 AG11
ACC03 ACC04 ACC08 SE01 SE02 SE04 SE05 SE06 SE07 SE09
SE10 SE11
probit DPA01 PRE1 SE06 SE07 ACC04

summarize SE06, meanonly
scalar SE06_M = r(mean)

summarize SE07, meanonly
scalar SE07_M = r(mean)

summarize ACC04, meanonly
scalar ACC04_M = r(mean)

nlcom (DAP:- (_b[_cons]+SE06_M*_b[SE06]+SE07_M*_b[SE07]+
ACC04_M*_b[ACC04])/_b[PRE1]), noheader //
//////////////////////////////////////////////////

// Maximum Likelihood Function//

generate DPA1 = 0
replace DPA1 = 1 if VAI==3 | VAI==4

// We generate a variable that tells us the answer
to the second question //

generate DPA2 = 0
replace DPA2 = 1 if VAI==2 | VAI==4

// We generate a single variable for the second
amount //

generate PRED = .
replace PRED = PRE2 if DPA1==1
replace PRED = PRE3 if DPA1==0

// Model without explanatory variables //
doubleb  PRE1 PRED DPA1 DPA2

// Model with explanatory variables //
doubleb  PRE1 PRED DPA1 DPA2 SE06 SE07 ACC04

// We find the willingness to pay //
nlcom (DAP:(_b[_cons]+SE06_M*_b[SE06]+SE07_M*_b[SE07]
+ACC04_M*_b[ACC04])), noheader

//// End ////
```