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INVESTIGACIÓN

Differences Between Parametric and Non-Parametric Estimation of Welfare Measures: An Application to the Río Claro, Talca, Chile

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ABSTRACT. In this article is presented the application of a contingent valuation method in a developing country to compare parametric and non-parametric welfare estimates associated to the use of a water resource. The statistical comparison uses the confident intervals for the individual's welfare measures and verifies whether these intervals overlap each other. Unlike the non-parametric case where there exist standard procedures to create confident intervals, in the parametric case a simulation is needed. This simulation procedure takes advantages of the asymptotically normal distribution of the parameters of the model. The results suggest that there is not a significant difference between parametric and non-parametric welfare measures. This can be explained appealing to the effort spend on the design of the survey, since it is well known that the distinction between parametric and non-parametric estimates is less important when the assumption about the distribution function of the willingness to pay is close to the true distribution.

Keywords: contingent valuation, non-parametric estimations.

Diferencias entre estimaciones paramétricas y no-paramétricas de medidas de bienestar: una aplicación al caso del río Claro, Talca, Chile

RESUMEN. Este artículo presenta la aplicación del método de valoración contigente en un país en vías de desarrollo donde se comparan estimaciones paramétricas y no paramétricas del bienestar asociadas al uso de un recurso de agua. La comparación estadística utiliza los intervalos de confianza de las medidas de bienestar y verifica si estos intervalos se traslapan. A diferencia del caso no paramétrico, donde existen los procedimientos estándares para crear intervalos confidentes, en el caso paramétrico una simulación es necesaria. Este procedimiento de la simulación toma ventajas de la distribución asintótico normal de los parámetros del modelo. Los resultados sugieren que no hay una diferencia significativa entre las medidas paramétricas y no paramétricas del bienestar. Esto puede ser explicada por el esfuerzo puesto en el diseño del cuestionario, ya que es bien sabido que la distinción entre las estimaciones paramétricas y no paramétricas es menos importante cuando el supuesto sobre la función de distribución de la disposición a a pagar está cercana a la verdadera distribución.

Palabras clave: valoración contingente, estimaciones no paramétricas.

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BACKGROUND

Contingent valuation *(CV)* is a method that estimates the economic value that individuals give to the flow of services generated by the environment. This is a direct method that is characterized by the creation of a hypothetical market, in which people have the opportunity to declare their preferences, and express their willingness to pay *(WTP)* for an improvement in the quantity or quality of a particular public good.

Since the work of Bishop and Heberlein (1979), a question instrument has been used in which the individuals are faced to a randomly assigned amount of money and they have to decide whether or not they accept to pay this amount of money. This format is broadly accepted as it mimics the decision that consumers find in a private goods' market, thus facilitating the answer of the respondent and reducing the possibility of bias due to the nature of the interview. This question instrument is known as dichotomic or referendum format, which is econometrically estimated through Logit or Probit models.

The initial works in *CV* with binary format have used the model of random utility proposed by Hanemann (1984). In this approach, the maximization process underlying on individuals at the time of answering the question instrument is explicitly recognized. Alternatively, other authors have used a more direct econometric estimation of the valuation function, which does not require any reasoning about the underlying optimization process in the individuals' preferences (Cameron and James 1987, Cameron 1988).

These methodologies give identical welfare measures for dual functional forms. According to McConnell (1990) the previous models are dual among them, the first reflecting a model from a utility function and the second reflecting a model from a expenditure function. Empirically, it has been shown that the welfare measures for linear and logarithmic functions are statistically equal (Vásquez *et al*., 1998).

For both proposals the estimation of welfare measures is subject to the functional form of the underlying indirect utility functions or the expenditure functions. Also, they depend on the inclusion or exclusion of other explanatory variables different from the bid amount, and on the assumptions respect to the probability distribution of errors. In this last case, an incorrect specification of these assumptions results in a biased estimation of the welfare measures.

At first sight, the errors in the estimation of welfare measures can imply wrong decisions in the allocation of resources. This is important in the context of developing countries where the shortage of resources has systematically favored projects framed in the traditional line of economic growth, delaying the environmental aspects and the protection of the natural resources.

With the purpose of overcoming the difficulties created by this problem the use of non-parametric methods of estimation of the welfare measures has been proposed (Kristrom 1990, Dufield and Patterson 1991, Haab and McConnell 1995 and 1997). This type of estimation does not require assumptions on the probability distribution of errors nor on the functional forms of the utility or expenditure functions. Additionally, the non-parametric estimation allow us to avoid the estimation of negative willingness to pay, that are common in parametric models and which are difficult to interpret economically.

The purpose of this article is to compare the non-parametric estimations of welfare measures, with the traditional ways of estimation. Testing the hypothesis of equality among welfare measures will provide us with a sense of the relevance of this topic in the context of developing countries and eventually learn about the effort that should be spend on this issue for future applications of CV.

The following section briefly outlines the Contingent Valuation Method *(CVM)* and the parametric and non-parametric estimation of welfare measures. The third section presents the application of the CV to value an improvement in water quality in a river located in Talca City (Chile). This section also shows the welfare estimates for both statistical approaches. Finally, some conclusions are presented in the last section.

ESTIMATION OF WELFARE MEASURES IN CONTINGENT VALUATION

Contingent valuation in a dichotomic format confronts respondents to a situation in which they accept or reject a suggested cost for a given product. Under this design, the researcher chooses m different values, $b_1, b_2 ... b_m$ and administers these costs within a hypothetical valuation question to $n_1, n_2 ... n_m$ sub-samples. Each respondent is only confronted with one bid amount randomly selected and he or she decides whether or not to pat this amount of money in a “take it o leave it” framework. Sometimes, a second bid amount (b_k) is present to the respondents; it can be larger or smaller than b_i subject to a positive or negative first answer, respectively. The welfare measures associated to this method are obtained through the estimation of the mean or median of the Willingness to Pay, which depend upon the coefficient estimated when maximizing a likelihood function as.

$$\ell = \ln\left[\underset{p_i=1}{\pi} (1 - G(b)) \underset{p_i=0}{\pi} (G(b)) \right] \qquad (1)$$

Where $G(b)$ represents the WTP cumulative density function, and p_i takes the value 1 when the respondent accept to pay the quantity b_i and it tales the value 0 otherwise.

Depending on the functional form used to the utility function, several functional forms to the welfare measures can be obtained. In our case we used the linear model suggested by Hanemann (1984) and the logarithmic model initially used by Bishop and Heberlein (1979) (see Ardila, 1994) .

In order to estimate the variances of the welfare measures a common simulation process suggested by Krinsky and Robb (1986) is used. It consists of generating a large sample of the regression coefficients, assuming that these coefficients are distributed like a multivariate normal distribution with mean and variance given by the matrices of coefficients and covariance obtained as an outcome from the maximum likelihood estimation. Using this matrices of means and variances a large sample of coefficients are generated randomly from the multivariate normal distribution. Afterwards, for each of these simulated outcomes, the corresponding welfare measures are calculated. The results is a sample of size N of welfare measures, where N is selected by the researcher. The simulated sample is then ordered in an ascending way, and by discarding the inferior and superior percentile of the distribution, the confidence interval is obtained.

In the case of non-parametric estimation the survival function is built from the costs vector b_i and their respective proportions of acceptance. The main reference articles are those published by Kristrom (1990), Duffield and Patterson (1991) and Haab and McConnell (1995).

Kristrom (1990) uses the pool-adjacent-violator algorithm (PAVA) to construct the WTP *Survivor Function* assuming a linear piece-wise function. This basically consists of ordering the results obtained from a simple dichotomic CV study, specifying the amount of affirmative answers k_i obtained by the offer of the cost vector b_i with respect to the total of the surveys made n_i, making the sequence of these proportions π_i, so that:

$$\pi_i = k_i / n_i \qquad (2)$$

Ayer *et al*., (1955) show that if π_i forms a monotone non-increasing sequence of proportions, then this sequence provides a distribution free maximum likelihood estimator of the probability of acceptance. If the sequence is not monotonic then the use of PAVA is suggested, so that if $\pi_i < \pi_{i+1}$, for some $i, (i = 1, 2, \ldots m-1)$, then $\overline{\pi}_i = \overline{\pi}_{i+1}$, where the bar denotes the maximum likelihood estimates, so that the proportions π_i and π_{i+1} are grouped and replaced by

$$\frac{k_i + k_{i+1}}{n_i + n_{i+1}}$$

This procedure is repeated until assuring that the sequence is decreasing and monotonic in i.

To complete the necessary information it is assumed that if the offered cost is zero ($b_o = 0$), then the probability for acceptance is equal to one ($\pi_i = 1$), and in addition some arbitrary point is chosen $b_T = T$, so that the probability for acceptance is equal to zero ($\pi_i = 0$). The value T represents the point where the *WTP* survivor function meets the horizontal axis. The allocation of a value T, allows to limit the *WTA* survivor curve guaranteeing the mean estimation defined as the area under this curve.

Using a linear interpolation the mean can be calculated by a trapezoid approach, the area to calculate is equal to the sum of the areas in each trapeze formed by the different ranks of values and their probabilities. If the data are ordered by p_i in the vertical axis and by b_i in the horizontal axis (see figure 1), the mean is defined by

$$C = \sum_{i}^{k} \frac{(p_i + p_{i+1})(b_i - b_{i-1})}{2} \qquad (4)$$

Where C is the welfare measure (mean). Alternatively Duffield and Patterson (1991) express the welfare measure as:

$$C = \sum_{i_i}^{k} \Delta b_i \; p_i \tag{5}$$

Where

$$\begin{aligned} \Delta b_i &= (b_{j+1} - b_{i-1})/2 \quad si\ i = 2\ldots, m-1 \\ \Delta b_i &= b_i + (b_2 - b_1)/2 \\ \Delta b_T &= (b_T - b_{T-1})/2 + (T - b_T) \end{aligned}$$

This form of expressing the mean has the advantage of giving the welfare measure variance directly. Assuming independence in the answers, and since the answer of an individual is a binomial random variable with n_i and π_i parameters, the variance of p_i is given by $\pi_i(1-\pi_i)/n_i$ Then the variance of C is:

$$Var\,(C) = \sum (\Delta b_i)^2 \pi_i (1-\pi_i)/n_i \tag{6}$$

On the other hand, the estimation of the median is obtained by a linear extrapolation taking into account that the value we are looking for is the one when the respondent is indifferent between accepting or rejecting b_j, that is, when $\pi_i = 0{,}5$.

From a similar perspective Haab and McConnell (1995, 1997) analyze the proportion of negative answers h_i resulting from the b_i costs proposed to the questioned individuals. The authors assume a Turnbull distribution, which is especially strong since it makes assumptions on the distribution of the willingness to pay and not assumptions on the utility function.

In this case p_i represents the probability that the real willingness to pay (noted as C) is found in the interval (b_{i-1}, b_i), that is:

$$p_i = P(b_{i-1} < C \le b_i) \quad for\ i = 1,\ldots, m+1 \tag{7}$$

With this specification, the cumulative distribution function is given by:

$$F_i = P(C \leq b_i) \; for \; i = 1, \ldots, m+1, \quad \text{y donde } F_{m+1} = 1 \qquad (8)$$

If (7) and (8) are completed, then the density function can be represented by the difference of the cumulative distribution function:

$$p_i = F_i - F_{i-1}, \text{ with } F_0 = 0 \qquad (9)$$

The Turnbull function can be estimated considering F_i and p_i as parameters, which implies a likelihood probability function:

$$L(F;h,k) = \sum_{i=1}^{m} \left[h_i \ln(F_i) + k_i \ln(1 - F_i) \right] \qquad (10)$$

Where k_i are the positive answers. If the proportion of negative answers (h_i) to the cost b_{i+1} is strictly larger than the proportion of negative answers to the cost b_i, then the probability that the WTP is in the interval (b_{i+1}, b_i) is positive and equal to the difference of the proportions.

Haab and McConnell (1997) summarize the estimation procedure in several stages, beginning by calculating F_i using:

$$F_i = \frac{h_i}{h_i + k_i}, \quad \text{for each i.}$$

Later F_i y F_{i+1} are compared (starting with j=1). If $F_{i+1} > F_i$, then the F_i are calculated. On the contrary, if $F_{i+1} < F_i$, then the corresponding cells to i and $i+1$, and their respective values of b_{i+1}, b_i should be grouped. The pooled cells have the purpose of forming an increasing monotonic probability distribution function. After this is accomplished the probability density function (p_i) is estimated as the difference between the cumulative function in i and $i-1$ given in formula (9). The variances associated to F_i and p_i parameters can be expressed by:

$$Var(F_i) = \frac{F_i(1-F_i)}{h_i + k_i} \tag{11}$$

$$Var(p_i) = \frac{F_i(1-F_i)}{h_i + k_i} + \frac{F_{i-1}(1-F_{i-1})}{h_{i-1} + k_{i-1}} \tag{12}$$

The central tendency measure used like a welfare measure is a lower bound of the WTP. This lower bound and its respective variance is calculated as it follows:

$$E(\lim\inf DAP) = \sum_{i=1}^{m+1} b_{i-1} p_i \tag{13}$$

$$Var\left(\sum_{i=1}^{m+1} b_{i-1} p_i\right) = \sum_{i=1}^{m+1} b_i^2 \left[Var(F_i) + Var(F_{i+1})\right] - 2\sum_{i=1}^{m+1} b_i b_{i-1} Var(F_i) \tag{14}$$

The advantages of these estimation methods are its easy application and the robustness of the welfare measure against specification errors.

ESTIMATIONS AND RESULTS

To determine the economic value that the inhabitants of the city of Talca (Chile) give to the improvement of the environmental quality of one of its main rivers (Río Claro), a dichotomous CV was applied. In this study the sample consisted of 500 questionnaires, of which six where considered unusable.

A second step in the experimental design is the selection of the bid amount vector in the survey. As Hanemann and Kanninen (1996) suggest, the main purpose of an optimal experimental design is to find a bid vector that enable us to obtain the maximum information about the parameters of the WTP distribution given a sample size. Some aspects related to the optimal design are interesting and pertinent, and recently they have been object of analysis within *CV* experiments with a clear emphasis in the logit model (see for example Alberini, 1995; Cooper, 1993; Duffield and Patterson, 1991 and Nyquist, 1992, among others). In general terms, an optimal design aims at the determination of the number of bid amounts, the specification of the values and the definition of the sub-samples' size, in such way that the important parameters are efficiently estimated.

Duffield and Patterson (1991), suggest a method of sample design that allows the determination of the optimal sub-samples allocation (n_i) given the total size and the vector of the offered costs. This criterion minimizes the mean WTP variance estimated with a non-parametric approach as established in equation 6. Cooper (1993) using the same criterion proposes a process known as *DWEABS* (Distribution With Equal Area Bid Selection) which finds the costs vector minimizing the mean square error ($\text{MSE} = \text{Variance} + [\text{Bias}]^2$). In the present work this last procedure was used, for which a preliminary test to obtain the *WTP* using an open-ended format. A Box-Cox test suggests that the *WTP* is asymmetrically distributed. With Cooper's algorithm gave six different annual costs (b_i =880, 1520, 2310, 3415, 5190 and 8950) to 494 observations. These can be found in **Table 1**.

With the results obtained in the survey and considering the bid amount b_j as the only explanatory variable as well as assuming that errors are distributed in a logistic form, the welfare measures for a logarithm functional form of the indirect utility were estimated annually in \$ 8639 and \$ 6953 for the mean and median respectively, where as for a lineal functional form, the mean (and median) is equal to \$6901. The estimation of their respective confidence intervals by the simulation method, are found in **Table 3**.

To compare the estimated welfare measures we use the criterion of confident interval overlapping, .i.e. whether or not the confident intervals overlap each other. We prefer this very simple method instead of a more traditional approach such as a t-test because we do not have the covariance among the welfare measures. Even though we could obtained, by means of a very sophisticated method, the covariance among the parametric estimates (see Vásquez, 1998), it is even more complicated to obtained a covariance among parametric a non-parametric estimates.

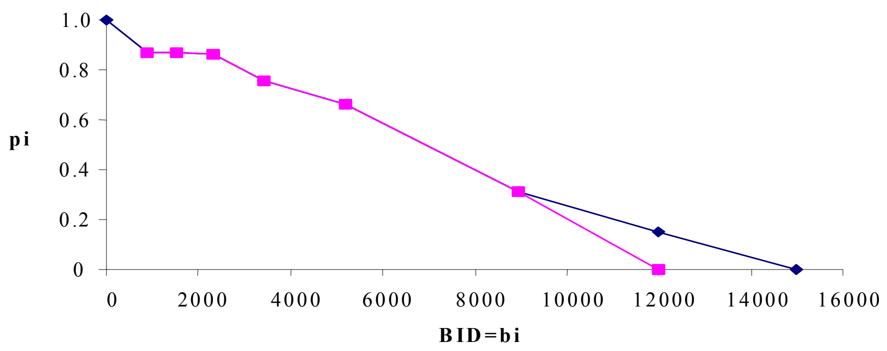
Regarding the proposition made by Kristrom, **Table 1** shows the proportion of positive answers obtained when offering the costs b_j. As seen in the data, it was necessary to consider $\pi_1 = \pi_2$ in order to assure the non-increasing monotonic condition of the *survivor function.*

Table 1. Tabulation of the questionnaire results

b_i	k_i	k_i / n_i	π_i
880	11	11/16	0.688
1520	42	42/45	0.933
2310	57	57/66	0.863
3415	75	75/99	0.757
5190	116	116/175	0.663
8950	29	29/93	0.311
Sub-total	330		

For the calculation of the mean two possible values for T were established: $T_1 = 12000$ and $T_2 = 15000$ (see **Figure 1**). Using the estimation by trapezoids the mean was calculated as 6524 and 6990 annual pesos respectively, whereas the median was calculated as 6934 annual pesos. The calculation of the variance was made using the equation presented in (6), and reached $215. The confidence interval appears in **Table 3**.

Figure 1. Survival function of WTP



When applying the Turnbull distribution (**Table 2**) it was necessary to group b_1 and b_2 to guarantee a monotonic increasing probability density function. Considering the group ranges, the inferior limit of the WTP was $5,189 annual pesos with a standard error of 210.57 pesos. It is observed that this value is in the 3415 - 5190 range, whereas the mean is in the 5190 - 8950 range, the latter determined by a $p_i = 0.5$ that with a linear approximation is equal to 6934.

Table 2. Calculation of the PDF and CDF

Range	Fi	PDA*	FDP*
0-880	0.31	0.13	0.131
		(0.043)	(0.043)
880 – 1520	0.07	Grouped	Grouped
1520-2130	0.14	0.14	0.005
		(0.042)	(0.060)
2310-3415	0.24	0.24	0.106
		(0.043)	(0.060)
3415-5190	0.34	0.34	0.095
		(0.036)	(0.056)
5190-8950	0.69	0.69	0.351
		(0.048)	(0.060)
8950 – up		1	0.312
			(0.048)

* values in brackets represent the standard errors.

The mean and median estimations obtained with the different methods are found in **Table 3**. It is clearly noticed that the mean obtained by the Haab and McConnell (1995) method represents a lower bound of *WTP* than that obtained by the VCM, and does not fall within the confidence intervals of any parametric estimators. On the contrary, with the trapezoid approach and considering a value of T = 12,000, the calculate value of the mean falls within the confidence interval estimated with a linear functional form, although it does not coincide in the case of the logarithmic form. On the other hand, in the instance where T = 15,000 the estimate mean falls within the confidence interval calculated for both functional forms.

Table 3. Parametric and non-parametric estimations of welfare measures

Estimation method	Mean	Median
1. Parametric		
a) Linear	6901	6901
	6298 – 7729	6298 - 7729
b) Logarithmic	8.639	6.953
	7038 – 12322	5987 - 8558
2. Non-Parametric		
a) Haab & Mc . Connell	5198	6.934
	4786 – 5609	5910 - 8950*
b) Kristrom		
• T = 12.000	6.524	6.934
	6102-6945	5910-8950*
• T= 15.000	7.913	6.934
	6568-7.411	5.910-8950*

Range where that mean falls. 1 dollar =530 pesos.

Due to the linear interpolation used, the median is equal in every non-parametric case. Also, these do not reveal significant differences from the ones calculated in the parametric form. As in other studies the median is more robust than the mean with respect to changes in the estimation method, in the functional forms, and in the assumptions about the errors distribution.

The results also show that the linear model overlap in about 45% with the first Kristrom's case. And in the other case one interval is completely inside the other interval. This is also true for the comparison of the medians. The only differences are given by the Haab and McConnell (1997) estimations, where there is not an overlapping. This result is completely expected since in their estimations they truncate the upper tail of the distribution producing an artificial reduction in the mean and in the intervals. Furthermore, another difference is found between the logarithmic functional form and the non-parametric estimations, where there exits an overlapping only with the second Kristrom's case which is close to a 16%. Additionally, the selection of the truncate range in Kristrom's proposal does not reflect statistical differences, since it does not alter the welfare measures substantially.

CONCLUSIONS AND RECOMMENDATIONS

If the Kristrom's method is compared with the linear parametric estimation the differences are not significant base on the overlapping of the confident intervals. There exists a significant difference when this method is compare with a logarithmic parametric estimation or when the Haab and McConnell approach is compare with the parametric estimates. The former result suggests that it is more important to pay attention to differences in functional forms in the parametric model than between parametric or non-parametric methods. The latter result confirms that the statistical treatment suggested by Haab and McConnell produces a lower bound for the WTP and, like so, it is useful in indicating the smallest value that a given environmental good represents for a community. In the context of the decision making this value is important mainly because the mean is sensitive to the model specification. None of these differences apply for the case of the median of the WTP.

According to our results the distinction between parametric and non-parametric estimation is not especially important for the range of the welfare measures. It is well known that when the assumption of the error distribution is adequate, then the difference between both methods is not significant. To this respect, it is important to mention that while designing the experiment, the effort in determining the WTP associated probability distribution and the use of optimization criteria to obtain the range of values, reduces the risk of these errors. Therefore, it is possible to conclude that it is better to spend time in the experimental design before using non-parametric estimation methods that loose the advantages of the underlying information in the traditional econometric models, like the incorporation of other explanatory variables in the valuation function.

Finally, similar to other applications of CV (Cerda *et al.*, 1997; McConnell y Ducci, 1989) the use of a linear functional form is adequate since it produce more conservative results in comparison with other functional form for the parametric models and additionally it does not present significant differences with the results of non-parametric estimations.

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