Journal of Environmental Science and Engineering A 6 (2017) 479-486
doi:10.17265/2162-5298/2017.09.005

An Application of 'Willingness to Pay' Method as a Quantifier for Environmental Impact Assessment

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Abstract: The preservation/restoration of natural environment is frequently entailing excessive cost (paid by people through taxation) while it is a source of additional income for both, the State and the people, due to tourism. Since the evaluation of this good cannot be in market terms, it is applied here in a modified version of the CVM (Contingent Valuation Method), which is used in experimental economics in order to investigate the significance that people put on this good and how much they might be WTP (Willing to Pay) for supporting activities concerning the preservation/restoration of Lake Kastoria. The WTP dependence on (i) external diseconomies; (ii) the expectations for property values' rise as a result of the restoration; (iii) the proximity of interviewees' residence to the lake; (iv) the opinion of the interviewee on the time and money spent to visit the lake; (v) the time and money the interviewees spent to visit the lake, as well as other dependencies (all taken as independent variables) are estimated by means of logit, probit, logistic and linear regression models. The optimal concentration C_{opt} of a pollutant in the environment can be determined as an equilibrium point in the tradeoff between (i) environmental cost, due to impact on man/ecosystem/economy; and (ii) economic cost for environmental protection, as it can be expressed by Pigouvian tax. These two conflict variables are internalized within the same techno-economic objective function of total cost, which is minimized. In this work, the first conflict variable is represented by a WTP index. A methodology is developed for the estimation of this index by using fuzzy sets to count for uncertainty. Implementation of this methodology is presented, concerning odor pollution of air round an olive pomace oil mill.

Key words: CVM (Contingent Valuation Method), environmental impact, WTP (Willingness to Pay), logit model, parametric approach, non-parametric approach, probit model.

1. Introduction

Lake Kastoria covers an area of 28 km^2 at an altitude of 630 m in the Kastoria Prefecture, northwestern Greece (Fig. 1), extending to the municipalities of Kastoria, Makedni and Vitsi. The lake, subject to the provisions of the Bern Convention (1979), the Bonn Convention (1979), and Council Directives 79/409 and 92/43, is part of the Natura 2000 network. Lake Kastoria is a very fragile shallow aquatic ecosystem, long stressed by the various rural (logging, agricultural wastes, stockbreeding, etc.), craft (tanneries, fur/leather production) and urban (e.g., sewer discharges, rubble depositions and extensive littering) activities of the area. The nearby wastewater treatment plant of Dispilio, which operates since 1991, managed to reduce to some extent wastewater inflows, yet the lake faces increasing water pollution problems, ecological degradation of the coastal line and loss in its aesthetic value [1, 2].

The aim of this study is to provide policy-makers with much needed information on the economic value of the benefits generated by the sustainable management of the Lake Kastoria. The preservation/restoration of natural environment is frequently entailing excessive cost (paid by people through taxation) while it is a source of additional income for both, the State and the people, due to tourism. Since the evaluation of this good cannot be in market terms, it is applied here in a modified version of the CVM (Contingent Valuation Method), which is used in experimental economics in order to investigate the significance that people put on this good and how much they might be WTP (Willing to Pay) for supporting activities concerning the

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Fig. 1 Lake Kastoria: nine rivulets flow into the lake; its depth varies from nine to ten meters which defines the lake as a shallow one.

preservation/restoration of Lake Kastoria [3, 4]. The WTP dependence on (i) external diseconomies; (ii) the expectations for property values' rise as a result of the restoration; (iii) the proximity of interviewees' residence to the lake; (iv) the opinion of the interviewee on the time [3, 4] and money spent to visit the lake; (v) the time and money the interviewees spent to visit the lake, as well as other dependencies (all taken as independent variables) are estimated by means of logit, probit, logistic and linear regression models [5, 6].

The optimal concentration C_{opt} of a pollutant in the environment can be determined as an equilibrium point in the tradeoff between (i) environmental cost, K_1 (C), due to impact on man/ecosystem/economy; and (ii) economic cost, K_2 (C), for environmental protection, as it can be expressed by Pigouvian tax. These two conflict variables are internalized within the same techno-economic objective function of total cost K (C), which is minimized. The first of them is an increasing function of C, with an increasing rate (i.e., $dK_1/dC > 0$, $d^2K_1/dC^2 > 0$), since the impact is disproportionally higher in the region of high C-values. The second of them is a decreasing function of C, with an increasing algebraic or a decreasing absolute rate (i.e., $dK_2/dC < 0$, $d^2K_2/dC^2 > 0$ or $d|dK_2/dC|/dC < 0$), since the economic cost is higher in the region of low C-values, signifying high efficiency achieved by disproportionally higher input of resources due to the validity of the law of diminishing returns. In case of increase of (i) information diffused into the population and (ii) consequent sensitization, the K_1-curve moves upwards to K'_1, becoming steeper since the difference from the initial position is larger in the region of high C-values, where the environmental impact is stronger; as a result, C_{opt} is shifting to C'_{opt}, where $C'_{opt} < C_{opt}$. It is worthwhile noting that the K_1-increase is expected as a function of time, since the public becomes more informed and more sensitive because of income increase and modern educational trends. On the other hand, a decrease of interest rate i implies decrease of subsidy optimal value I_{opt} (and consequent increase of capital cost for the investor [1, 2]), since $\partial I_{opt} / \partial i > 0$, as it is shown in the Appendix; consequently, K_2 moves upwards to K'_2 becoming also steeper since the difference from the initial position is larger in the region of low C-values, where the economic cost is disproportionally higher due to the validity of the law of diminishing returns; as a result, C_{opt} is shifting to C''_{opt}, where $C''_{opt} > C_{opt}$ (Fig. 2).

The environmental cost can be represented, in a rather subjective way, by 'WTP', which is defined as the maximum amount of money a person would be willing to pay/sacrifice/exchange in order to get rid of a polluting source. The assignment of values on this index is performed by experts, who make their estimates under uncertainty, which is higher when measurements of the impact of the corresponding

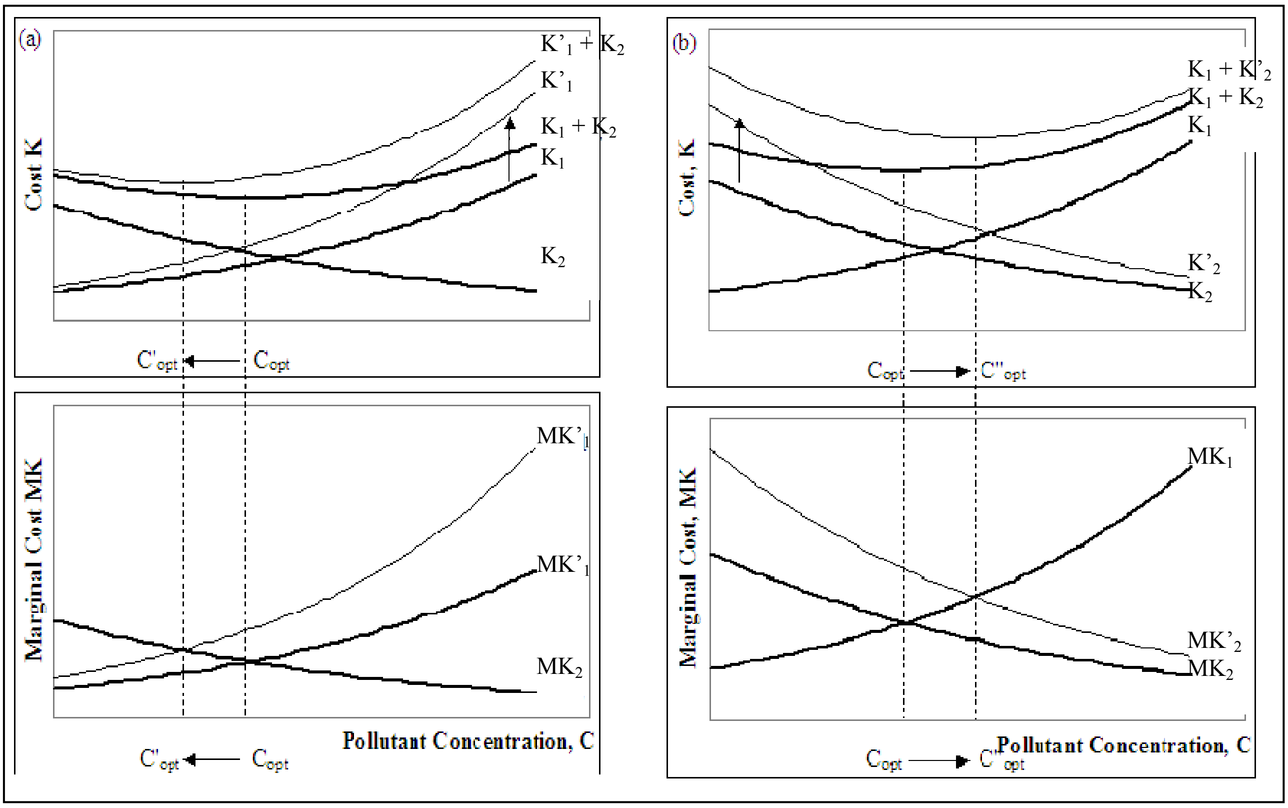


Fig. 2 The dependence of environmental cost K_1 and economic cost K_2 on pollutant concentration C; the shifting of optimal value C_{opt} is also shown in the case of (a) information diffusion and consequent sensitization of the public; and (b) decrease of interest rate, implying decrease of subsidy and consequent increase of capital cost for the investor.

pollutant are impossible, due to the subjective nature of the implied result on human. In this work, it is presented the design/utilization of conditional WTP index based on fuzzy reasoning, capable to count for uncertainty under a variety of conditions that influence decisively the experts' opinion, as e.g., in the case of odor pollution of air, where the application of standard practices, like the ASTM E 544-99 (2004), is based on odor intensity referencing scales made of crisp numbers, standing for pollutant concentrations, usually following a geometric progression scale [7, 8].

2. Methodology

Members of the public were randomly intercepted in city and town centres, cafes and markets, and were interviewed face-to-face. The sample size was 80 questionnaires. For the processing of answers in stages 10, 12, 17 (pilot, main, follow-up study, respectively), these measures/indices are used [2, 5]: R^2, Efron's R^2, MacFadden's log likelihood of the intercept model, Cox & Snell's R^2 and adjusted Cox & Snell's R^2. The non-linear regression models used are the probit and the logit ones. Probit is a popular specification for an ordinal or a binary response model that employs a link function. In this model, the response variable y is binary and may represent a certain condition [6, 9]. A generalized form of this model is as Eq. (1):

$$\Pr(y = 1/x) = \Phi(x'\beta) \qquad (1)$$

where Pr denotes probability and Φ is the cumulative distribution function of the standard normal distribution. The parameters β are typically estimated by maximum likelihood. There exists an auxiliary random variable as Eq. (2):

$$y^* = x'\beta + \varepsilon \qquad (2)$$

where error $\varepsilon \in N(0,1)$, then y can be considered as an indicator for whether this latent variable is positive as Eq. (3):

$$y = 1_{\{y^* > 0\}} = \begin{cases} 1 & if \quad y^* > 0, \quad i.e., -\varepsilon < x'\beta \\ 0 & otherwise \end{cases} \quad (3)$$

The logit model gives the logistic function as Eq. (4):

$$f(z) = \frac{e^z}{e^z + 1} = \frac{1}{1 + e^{-z}} \quad (4)$$

where the variable z is usually defined as: $z = \beta_0 + \beta_1 x_1 + ... + \beta_k x_k$ where β_0 is the intercept and $\beta_1,...,\beta_k$ are the regression coefficients of $x_1,...,x_k$, respectively. Actually, R^2, the coefficient of determination, is the relative power of the probit and the logit models [6].

For the purpose described, a methodological framework was developed, under the form of an algorithmic procedure including 8 activity stages and 2 decision nodes:

(1) Determination of (i) the borders of the geographical area under consideration and (ii) the interval of values for each pollutant and physical parameter that may appear in this area (including frequency and impact on human/ecosystems/infrastructure);

(2) Experimental design;

(3) Performance of observations and measurements in both modes, laboratory (after sampling) and *in situ*;

(4) Design/development of the corresponding stochastic model;

(5) Selection of panelists/experts, i.e., individuals capable to assign subjective values on indices representing environmental impact;

(6) Fuzzy partition (by panelists, possibly aided/guided by algorithmic procedures as described in technical literature) for the universe of each set of values corresponding to input-output variables, after associating each of these values with a class;

(7) Determination (by panelists) of conditional statements in the form of fuzzy rules as: IF x is P, THEN y is Q, where x and y are linguistic variables, P and Q are linguistic values defined by fuzzy sets on the universe of discourse X and Y, respectively;

(8) Implementation by testing through selected specimen runs.

(a) Do the interval limits justify further investigation?

(b) Are there enough numerical data for statistical inference?

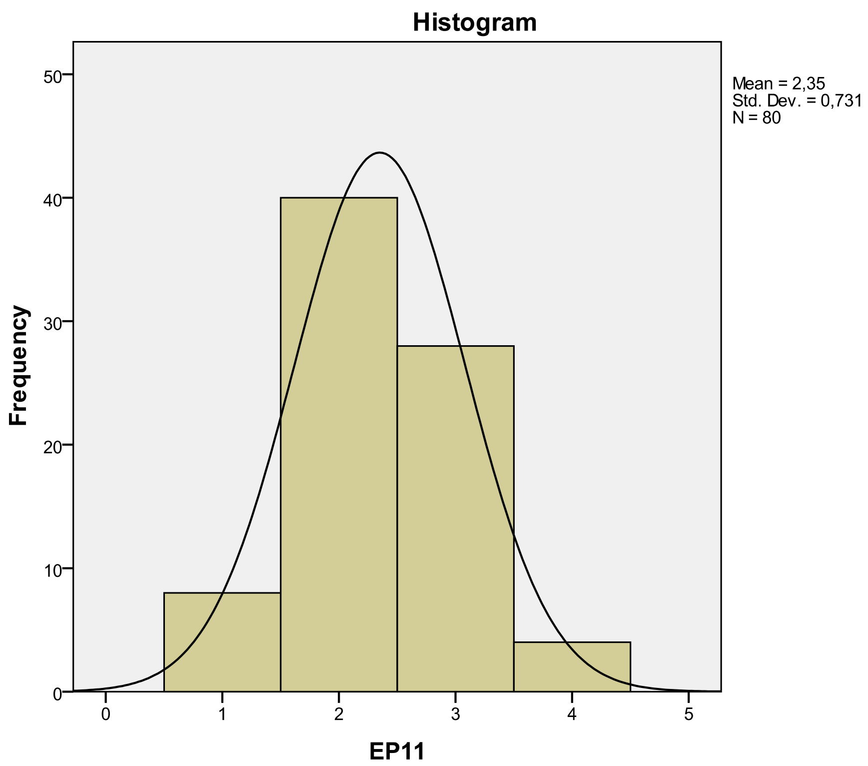
3. Statistical Data and Results

The survey sample consisted of 51.25% women and 48.56% men, the majority between 26 and 35 years old, since young people were more willing to participate in the survey; 27.5% of the respondents hold a university degree, whereas 37.50% had high school education. The majority of the interviewees belonged to the intermediate income class and enjoyed full-time employment. About 50% of the respondents live or work in close proximity of the lake; however, average WTP does not differ significantly with proximity or distance. Given that extensive media coverage during the recent years, most people were well aware about the problems of the lake. When respondents were asked to assign a level of importance to the protection of the lake on a 3-point scale (very, enough and slightly), 93.75% placed it at the highest scale, 11.25% at the medium scale and only 5% at the lowest.

The present survey examined, among other factors, the attitude of citizens towards the general environmental problems of the area and the benefits that would derive from restoring the lake's ecosystem. The majority of the interviewees allocate the responsibility of environmental degradation to the failure or limited capacity of the State and local authorities, whereas they support all of the restoration activities which were proposed, with 69.03% giving high priority to biological agriculture for decreasing the input of chemical contaminants. The participants were also asked to determine the amount of money, among six fixed alternatives and a seventh open option, that each was willing to pay for 12 months to help maintain or even improve the state of the lake, taking into consideration that the subsidy which was given by the government and the local authorities should remain the same. The proportion of all respondents who expressed a WTP any amount was 90% (Fig. 3); the mean WTP was 13.16 €, while the amount of 5 € was the most frequent.

Regression analysis was also used to investigate the relationship between WTP and socio-economic factors; the Durbin-Watson statistic of ca. 2 is indicative of small residual autocorrelation (Table 1), whereas the ANOVA (Analysis of Variance) is shown in Table 2. The analysis results found which independent variables are statistically significant at the 5% significance level: X_9: the importance of Lake Kastoria; X_{12}: WTP if the respondent was living close to lake; X_{14}: accept a compensation to forgo an improvement in lake; X_{19}: own property close to lake; X_{28}: household income in relation to that of residents of Kastoria. The reduced form of the resulting linear regression function becomes Eq. (5):

$$WTP=1.164-0.27X_9+0.82X_{12}-0.14X_{14}-0.01X_{19}+0.11X_{28} \quad (5)$$



Statistics

N	80
Mean	2.35
Std. Error of Mean	0.082
Median	2
Mode	2
Std. Deviation	0.731
Variance	0.534
Skewness	0.142
Std. Error of Skewness	0.269
Range	3
Min	1
Max	4

Fig. 3 Distribution of WTP and sample summary statistics.

Table 1 Regression analysis model summary.

R	*R^2*	*Adjusted R^2*	*Std. error of the estimate*	*Durbin-Watson*
0.929	0.863	0.819	0.311	1.885

Table 2 The ANOVA results, with predictors: X_1, …, X_{16} and WTP-value as the dependent variable.

Model	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Regression	36.408	19	1.916	19.851	0.00
Residual	5.792	60	0.097		
Total	42.200	79			

*Note: *df* means degree of freedom.

Table 3 Probit and logit regression analysis.

Probit			
	Chi-square test	df	Significance
Pearson	35.065	218	1.000
Deviance	42.050	218	1.000
	Chi-square test		
Cox & Snell	0.888		
Nagelkerke	1.000		
McFadden	1.000		
Logit			
	Chi-square test	df	Significance
Pearson	28.297	218	1.000
Deviance	27.774	218	1.000
	Chi-square test		
Cox & Snell	0.888		
Nagelkerke	1.000		
McFadden	1.000		

Table 4 The fuzzy rules defined as conditional statements in IF-THEN form (3-scale partitioning).

IF	IF	THEN	IF	IF	THEN	IF	IF	THEN
C	T	N	C	T	N	C	T	N
Low	Low	Low	Medium	Low	Medium	High	Low	High
Low	Medium	Low	Medium	Medium	Medium	High	Medium	High
Low	High	Medium	Medium	High	High	High	High	High

The results of the logit and probit regression analysis are shown in Table 3. The independent variables, statistically significant at the 5% significance level, for probit regression are X_{12} and X_{14}, whereas logit regression adds also the variable X_{19}.

The methodology described has been implemented in the case of measuring odor intensity. The odorant considered was associated with particles emitted from the chimney of an olive pomace oil mill in Crete [3]. The ranges taken into account for fuzzy partitioning of input variables (concentration C, temperature T, humidity H and wind velocity W) were determined by measurements *in situ* and by estimating the parameter values of the corresponding model as it is in the Table 4. For example, the range for concentration was extracted by applying a double Gaussian model of dispersion (Fig. 3).

In conclusion, the functionality of the methodological framework, developed/presented herein under the form of an algorithmic procedure including 8 activity stages and 2 decision nodes, for estimating a conditional index as a quantifier for environmental impact assessment was proved by means of a simple numerical case example based on data extracted from a study concerning odor pollution of air round an olive pomace oil mill.

4. Conclusion

Economic valuation is a two-part process in which the first part (demonstration) displays and measures the economic value of environmental assets, while the second part (appropriation) finds ways to capture the value of such. The present survey has managed to demonstrate the economic value of preserving Lake Kastoria; the appropriation of this value requires policies, rules and regulations on the part of concerned agencies and institutions.

WTP, a so-called 'restoration fee', which is actually a 'user's fee' [5], indicates the possibility of fund raising from the community, especially when lake restoration is linked to tourist economy. On the other hand, non-use values for the lake, which this study shows to be substantial, can be captured through appropriate policy instruments. Designing appropriate policy instruments is one big task in itself and there are possible options to be considered like voluntary contribution or council taxation. Since education is a determinant that increases WTP in the medium/long-run, future surveys should target schools, colleges and universities in the area, so as to increase potential 'capturable' non-use values and acquire relevant information useful for sensitizing young people.

In conclusion, this analysis demonstrates that social science research can provide useful information for complex environmental policy problems such as the restoration of a lake system. Policy analysis for such cases is especially difficult because these systems provide multiple, interdependent services that vary by type of lake, location, ecohydrological management and other factors. The work presented herein has been proven a useful comprehensive tool for determining the realistic cognitive burden for stakeholders and third parties.

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Appendix

Given the function of optimal subsidy $I_{opt} = g\ (K, F, S, i, r, f, t)$, where K is the fraction of environmental benefit/improvement/gains (assessed in monetary units) deducted per time period by the State from its welfare budget; F is the gains during the first time period; S is the amount of investment for installing the unit intended for prevention of odor pollution of air; i is the interest rate used for money equivalence over time; r is the return on the best alternative investment (called 'the second best' in comparison with the first best for the State, which is the amount of subsidy $I_{opt}S$); f is the rate of F increase per period ($f > i$); t is the number of time periods (dimensionless) considered for depreciation, it has been proved that $\partial I_{opt} / \partial i > 0$ as Eqs. (1)-(3):

$$I_{opt} = \frac{KF\,(1+i)^{t-1}}{S(1+r)^t}\,\frac{\left(\frac{1+f}{1+i}\right)^t - 1}{\frac{1+f}{1+i} - 1} \Rightarrow I_{opt} = \frac{KF}{S(1+r)^t}\,\frac{(1+f)^t - (1+i)^t}{(1+f) - (1+i)} \tag{1}$$

$$I_{opt} = \frac{KF}{S(1+r)^t}\left[(1+f)^{t-1} + (1+f)^{t-2}(1+i) + \ldots + (1+i)^{t-1}\right] \Rightarrow I_{opt} = \frac{KF}{S(1+r)^t}\sum_{j=t-1}^{0}(1+f)^j(1+i)^{(t-1)-j} \tag{2}$$

$$\frac{\partial I_{opt}}{\partial i} = \frac{KF}{S(1+r)^t}\sum_{j=t-2}^{0}\left[(t-2)+(1-j)\right](1+f)^j(1+i)^{(t-2)-j} > 0 \tag{3}$$