Measurement of Willingness to Pay
by Using Fuzzy Theory[*]

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I. Introduction

Contingent Valuation Method(CVM) has been widely used for the valuation of non-market goods. Since the method depends on survey

technique with regard to hypothetical situations, it could estimate non-use value as well as use value of goods in question. At the same time, the method loses its accuracy of measurement due to its dependence on survey technique. The error sources are design bias, hypothetical bias, strategic bias, and so forth which are mainly related to the design of survey questionnaire.

There has been many efforts to deal with the bias problem in CVM by altering questions regarding the willingness-to-pay(WTP).[1] Even if these trials could improve statistical efficiency of estimates by reducing some sources of bias, there still remains the uncertainty regarding respondents' WTP(Hanemann, 1984; Hanemann and Kriström, 1995; Li and Mattsson, 1995; Loomis and Ekstrand, 1998). This is the problem of preference uncertainty, which exists especially in the dichotomous choice CVM, since respondents in the survey are not 100% sure about their answer('yes' or 'no') to the suggested bid.

The main sources of the preference uncertainty would include respondents' incomplete knowledge about the non-market goods and inexperience of responding survey questions. This may be true when the respondents do not recognize the goods in question and/or they do not fully understand the terminology used in the survey. Also, if the respondents are not experienced to exam or value the non-market goods or environmental change, then they could not certainly state their WTP.

Regarding the preference uncertainty, Li and Mattsson (1995) assume

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1) The early style of questioning technique such as 'open-ended', 'payment card method', and 'bidding game method' tends to be changed to 'dichotomous choice form'. Further the 'single-bounded' dichotomous form has been developed to 'double-bounded', 'triple-bounded', etc.

that each respondent does not know the magnitude of valuation with certainty although the individual has a true valuation of the goods in survey. Under this assumption, they elicit a post-decisional confidence measure(0~100%) by a follow-up question, and integrate the measure into the standard discrete choice CVM. Thus they show that the above treatment provides more efficient contingent value estimates.

However, as we mentioned above, the main sources of the preference uncertainty are not the respondent's confidence level on the magnitude of value, rather their incomplete knowledge and inexperience of responding survey questions. In this circumstance, respondent would not know his/her true valuation of the resource. Then, the approach adopted by Li and Mattsson does not seem to successfully deal with preference uncertainty for the measurement of WTP. Further, the approach adopted to reflect respondent uncertainty could potentially introduce additional variance into the analysis(Loomis and Ekstrand, 1998).

In this respect, we attempt to measure the confidence level of WTP measure and to examine factors affecting the degree of uncertainty by using Fuzzy set theory. Our purpose in this paper is not to estimate a statistically efficient WTP. Rather we try to figure out how confidently we could believe the estimated WTP.

In the following section II, we introduce fuzzy theory and its application to measure WTP. Section III reports the analytical framework using fuzzy theory and the estimation results. Some concluding remarks are given in section IV.

II. Fuzzy Theory for Measuring WTP

1. Crisp Responses vs. Fuzzy Responses

Let x be an element of crisp set A, the membership of x can be defined as equation (1).

$$
\begin{aligned}
\mu_A(x) &= 1, & x \in A \\
&= 0, & x \notin A
\end{aligned}
\tag{1}
$$

In this notation, $\mu_A(x)$ indicates the membership of the element x in set A. Thus, for the crisp set, the membership of an element is either 1 or 0: i.e., full membership $(\mu_A(x) = 1)$ or full non-membership $(\mu_A(x) = 0)$.

Suppose $\tilde{A}$ is a fuzzy set which contains characteristical elements. An example of fuzzy set would be a group of young men. Another example would be the degrees of temperature which indicate 1 for too hot, 2 for too cold, and other numbers between 1 and 0 for not too hot or not too cold. Thus, the numbers assigned in the interval [0, 1] indicate degree of membership to a fuzzy set $\tilde{A}$.

In a standard dichotomous choice CVM, WTP is usually estimated by using crisp response as seen in panel (a) of <Figure 1>. The membership of the response for 'Yes' or 'No' to the elicited bid (t_i) is either one or zero since the discrete responses of this method are the elements of a crisp set. However, if we use fuzzy responses, we could obtain membership numbers between zero to one. The panel (b) of

〈Figure 1〉 Crisp Response vs. Fuzzy Response to Elicited Bids

(a) Crisp Response (b) Fuzzy Response
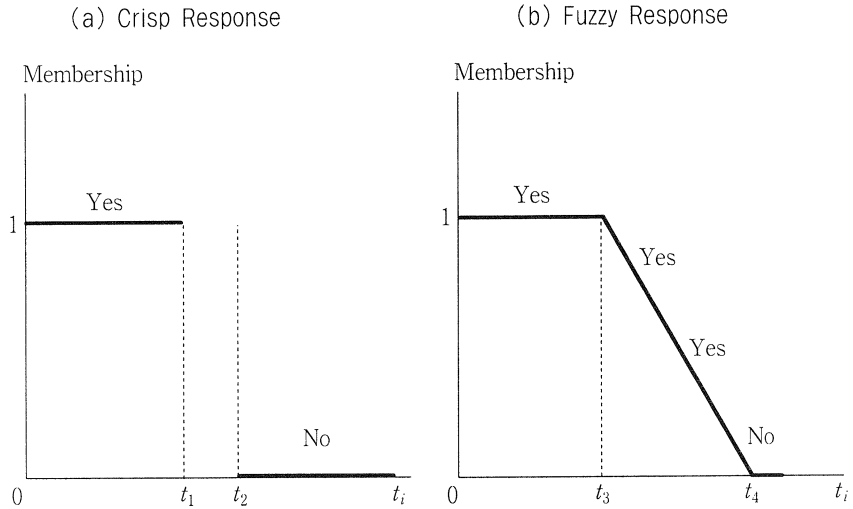
<Figure 1> shows the membership of 'Yes' responses which are dependent on the amount of elicited bid. Thus the membership varies from 1 to 0.

2. Fuzzy Membership Function

In general, a dichotomous choice format-formed questionnaire requires respondents to determine one of two alternatives, for, example, 'Yes' or 'No'. in the question of 'willingness to pay' the amounts produced in the questionnaire. But, strictly speaking, such reply of 'Yes' or 'No', that most respondents stated in a questionnaire, can lead certainties arising from several factors.

In order to make an exact judgement for the predicted results, it makes sense to perceive the 'certainty' that respondents have in their responses

of 'Yes' or 'No'.

The level of amount that respondents are willing to pay, or in contrast, they are, by no means, willing to pay, can be usually regarded as the 'certainty', of the response, or 'membership' 1.

Concerning the 'upward' or 'downward' level of the amount, it can be referred that various 'membership' exists from figure less than 1, to zero.[2] Such series can be reckoned at Fuzzy membership function, which estimates the 'uncertainty'.

The research has applied 'triangular fuzzy function' appropriate for measuring the 'uncertainty' from a dichotomous choice format questionnaire, and at the same time, the function most frequently employed among various 'membership function'.

<Figure 2> shows an asymmetric triangular fuzzy function. Now consider three points in the horizontal axis for x: $a - d_1$, a, and $a + d_2$ in which d_1 indicates the left-ward distance from the center point a and d_2 does the right-ward distance form a. From the triangular fuzzy function $\widetilde{F} = \{d_1, a, d_2\}$, a fuzzy membership function $\mu_{\widetilde{F}}(x)$ can be defined as equation (2)

$$
\begin{aligned}
\mu_{\widetilde{F}}(x) &= 1 - \frac{a - x}{d_1}, \quad a - d_1 \leq x \leq a, \\
&= 1 - \frac{x - a}{d_2}, \quad a \leq x \leq a + d_2, \\
&= 0, \quad \textit{otherwise}.
\end{aligned} \tag{2}
$$

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2) For the 'uncertainty', the figure is indicated at less than 1.

〈Figure 2〉 Asymmetric Triangular Fuzzy Function
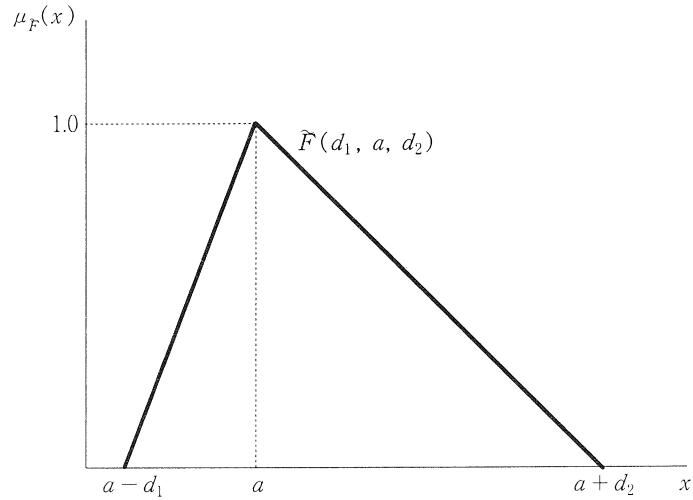
When x deviates from a infinitely left-ward, the fuzzy function becomes $\widehat{F} = (\infty, a, d_2)$ which changes the membership function as given by equation (3).

$$
\begin{aligned}
\mu_{\widehat{F}}(x) &= 1, & x \leq a \\
&= 1 - \frac{x-a}{d_2}, & a \leq x \leq a+d_2 \\
&= 0, & \textit{otherwise.}
\end{aligned} \tag{3}
$$

If d_2 becomes infinity, then a different membership function is defined as equation (4).

$$
\begin{aligned}
\mu_{\widehat{F}}(x) &= 1, & x \geq a \\
&= 1 - \frac{a-x}{d_1}, & a - d_1 \leq x \leq a \\
&= 0, & \textit{otherwise.}
\end{aligned} \tag{4}
$$

Now we try to apply this fuzzy function to a dichotomous CVM which elicits a bid as a WTP for environmental conservation or preservation of endangered species. Suppose a respondent is for sure willing to pay the elicited bid up to point a in <Figure 2>. Then we assign the value 1 as the membership for the elicited bid. As the bid amount becomes larger than point a, the membership gets smaller than 1, and eventually becomes zero as seen equation (3). This represents the membership for 'Yes' response. Likewise, the membership for 'No' response can be obtained by equation (4).

Ⅲ. Empirical Analysis of WTP by Using Fuzzy Theory

In this paper, we attempt to estimate the WTP for preserving the Asiatic Black Bear(ABB) in Korea which has been identified as critically endangered in Korean peninsula. By using Fuzzy theory, we try to figure out how confidently we could believe the estimated WTP. In this effort, Fuzzy theory is applied to a dichotomous choice CVM.

A survey was conducted for 500 adults selected in seven metropolitan areas from April to May in 2004. Out of 500 surveyed samples, we could use 473 samples for our analysis after discarding the questionnaires with irrelevant responses. The elicited amount of bid was selected among 1,250, 2,500, 5,000, 7,500, 10,000, 15,000, and 20,000 Korean Won per month. Each respondent was asked if she/he could pay a suggested bid for twelve months for supporting the efforts of preserving the ABB in Korea.

〈Table 1〉 Definition of Socio-economic Variables

Variable	Definition	
REC	Recognition regarding whether the asiatic black bear(ABB) was recorded as endangered species	1 if recognized; 0 otherwise
PRV	Degree of support to the necessity of preserving the ABB	4 highest; 1 lowest (4, 3, 2,, and 1)
INF	Degree of opinion regarding the influence of the ABB to human being	5 very positive; 1 very negative (5, 4, 3, 2, and 1)
DOB	Experience of direct observation of the ABB	1 if yes; 0 if no
IOB	Experience of indirect observation of the ABB via mass media	1 if yes; 0 if no
CHR	Degree of knowledge regarding the characteristics of the ABB	4 if know very well; 1 do not know well (4, 3, 2, and 1)
SEX	Gender of the respondent	1 if male; 0 if female
AGE	Respondent's age	years old
INC	Respondent's monthly household income	Korean Won
FAM	Number of family	persons
EDU	Education level of the respondent	Schooling years

In addition to the elicited bid amount, the socio-economic variables in our analysis is defined in <Table 1>. These variables are concerned in order to examine their relationship with the uncertainty or membership of WTP. <Table 2> reports descriptive statistics of selected variables.

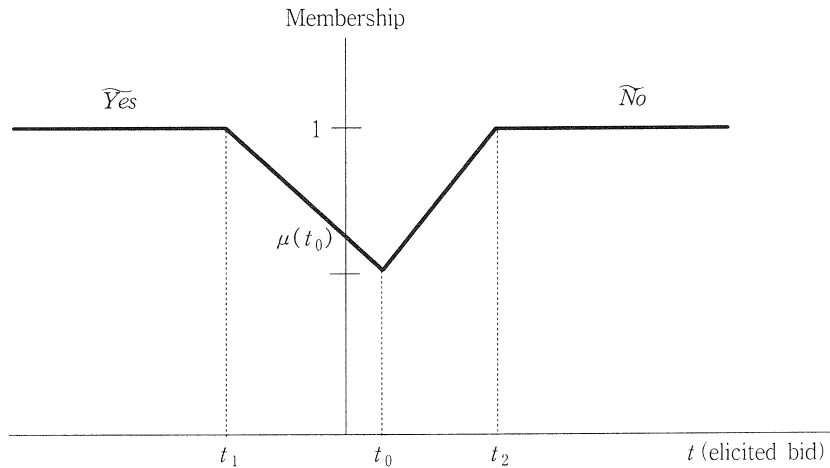〈Table 2〉 Descriptive Statistics of Selected Variables

Variable	Mean	Standard Deviation
REC	0.74	0.43
PRV	3.42	0.54
INF	3.40	1.24
DOB	0.32	0.45
IOB	0.97	0.23
CHR	2.03	0.61
SEX	0.50	0.43
AGE	26.70	9.34
INC	2,524,000	1,284,486
FAM	3.66	1.33
EDU	13.57	1.53

1. WTP Estimation in Fuzzy CVM

In this paper, we followed a post-decisional confidence procedure as used by Li and Mattsson (1995). However, our approach is different from them in that we did not attempt to estimate probability of paying bid. In our analysis, the main concern is given to the fuzzy membership through the follow-up question regarding respondents' confidence on their 'Yes' or 'No' responses to the elicited bid amount. After selecting 'Yes' or 'No' response, each respondent was requested to report the confidence level of the previous answer from 1 to 0. The relationship between the membership of the discrete choice and the estimation of WTP are explained below.

The Fuzzy curve $\widehat{YES}$ represents the membership of 'Yes' responses to the different amount of the elicited bid, while the Fuzzy curve $\widehat{NO}$ shows

〈Figure 3〉 Estimated WTP and Confidence Index

the membership of 'No' responses. The degree of membership varies from 10 depending upon the confidence of respondent to the elicited bid amount.

When the bid amount is too low, the respondent is 100% sure to answer 'Yes'. However, this confidence gets below 1 when the bid reaches a certain amount, for example, t_1 in 〈Figure 3〉. After t_1, the membership function of 'Yes' response becomes a monotonically decreasing function.

Now consider a big amount of the bid larger than t_2 in 〈Figure 3〉. The membership of 'No' response would be 1. As the bid amount gets smaller than t_2, the membership of 'No' response will be reduced below 1, showing a monotonically increasing shape.

The estimated amount of WTP is determined by the point of intersection between the $\widehat{YES}$ curve and the $\widehat{NO}$ curve. At the

intersection, we could obtain t_0, the estimated amount of WTP, and $\mu(t_0)$, the degree of confidence of the estimated WTP.

2. The Estimation Result

<Table 3> shows an OLS estimation results, in which the dependent variable is the membership of 'Yes' or 'No' responses and the explanatory variables are the variables defined in <Table 1> and the elicited bid.

The result of 'regression analysis that the research has conducted, shows that the variables of INC(Income standard), and EDU(Educational standard) have little close relations. This is cited as the rare phenomenon which makes a stark distinction from the general trend arising from the results of other researches which have measured the value of environmental resources. As an instance, Asiatic Black Bear, is considered as the special existence in Korean sentiment, unlike other environmental resources. In other words, a bear not only appears in the Korean traditional legend of the birth of Dankyun', known to have founded the nation, for the first time, but also it is often illuminated as materials of documentary data. Judging from the fact that a bear is mainly cited in Korean media, it plainly demonstrates that a bear is very familiar animal to Koreans.[3] Most Koreans aware that it is a pressing task to preserve and protect environment under the auspice of the government, as the animal is on the verge of fatal extinction. In conclusion, the willingness for respondents to pay the amount seems not to be greatly determined by INC and EDU. The analytic result proves

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3) The outcome of a questionnaire indicates that a majority of people think Asiatic Black Bear of social and friendly animal, as a pet, rather than wild animal.

that most respondents tend not to substantially consider of whether Asiatic Black Bear will have a positive effect or negative effect on human life.

According to the estimation result, only the elicited bid (t) variable significantly influence both the 'Yes' and 'No' responses' memberships. No other variables significantly influence the membership of both responses.

Membership Function of 'Yes' and 'No', employed in the research, has been assessed with the application of estimated outcome of 'regression analysis', and 'linear programing' of triangular fuzzy numbers.

$$\mu_{\overline{YES}} = atanh^{-1}(bW + C) + \frac{1}{2} \ , \quad a, b, c \in R, \quad a > 0,$$

$$\mu_{NO} = \frac{1}{2} atanh(dW + e), \quad d, e \in R, \quad d > 0.$$

The contrast graphs of 'Yes' group and 'No' group function to examine the 'membership' of the reply of 'willingness to pay' the finally-earmarked ceiling amount, in other words, to examine 'uncertainty' in the willingness to pay it.

In this respect, we formulated a linear form of membership functions by selecting only t variable. The resulting membership functions are given below.[4]

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4) Generally, fuzzy members can be shown in the form of linear, exponential, hyperbolic and piecewise linear. This research uses linear programming structure proposed by Bellman and Zadeh (1970). Hersh and Caramazzn (1976) proposed in their research that membership functions are best predicted in a hyperbolic structure but there is yet academic agreement on superiority and legitimacy of a function form for a membership.

'YES' membership function : $\mu_{\overline{YES}}(t) = 0.79645 - 0.05224t$

'NO' membership function : $\mu_{NO}(t) = 0.75146 + 0.071154t$

By solving the above equations, we can obtain the estimate of WTP and its confidence level. The estimated WTP for supporting the efforts of preserving ABB in Korea is 9,090 Korean Won per month(about 8 US$).[5] Since the WTP was requested for 12 months, the total estimated WTP per household become 109,080 Korean Won(about 90 US$). However, this estimated WTP is not 100 percent certain. Our Fuzzy analysis gives us 78 percent of confidence due to the existence of preference uncertainty of the respondents.

IV. Conclusion

While Contingent Valuation Method(CVM) has been popular as a convenient approach for valuing non-market goods, it sometimes looses its credibility due to several bias inherent in the survey procedure. Although many trials could improve statistical efficiency of willingness-to-pay estimation by reducing some sources of bias, there still remains the uncertainty regarding respondents' preference.

In this paper, we attempted to estimate the WTP by using fuzzy theory in order for dealing preference uncertainty problem in a discrete

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5) This has been calculated with the tool of two equation. The result shows that the two graphs make difference in the level of 0.78 of 'membership', marked in the vertical axis. Then, the amount produced at the horizontal axis is earmarked at some 9,990 won.

〈Table 3〉 Estimation Result

Variable	'Yes' Group			'No' Group		
	Coefficient	Standard Error	t-Statistic	Coefficient	Standard Error	t-Statistic
REC	0.041	0.035	1.17	0.0117	0.046	0.254
PRV	0.053	0.049	1.08	-0.0014	0.037	0.038
INF	-0.00053	0.004	-0.13	-0.0223	0.016	-1.394
DOB	0.019	0.030	0.63	-0.0054	0.043	-0.126
IOB	-0.024	0.092	-0.26	0.230	0.101	2.277*
CHR	0.0038	0.026	0.146	-0.0052	0.031	-0.168
SEX	-0.0085	0.029	-0.29	-0.308*	0.027	11.41
AGE	0.0020	0.0015	1.33	0.16E-04	0.20E-06	80.0*
INC	0.157E-07	0.89E-8	1.87	-0.53E-08	0.79E-08	-0.625
FAM	0.0096	0.012	0.80	0.0516	0.0032	16.13
EDU	-0.0028	0.0089	-0.31	0.0065*	0.196E-04	331.6
t	-0.052*	0.0034	15.29	0.071*	0.0038	18.68
Constant	0.797	0.179	4.45	0.752	0.164	4.59
Dependent Variable: Membership						
R^2	0.72			0.89		
Log likelihood	57.6907			-50.0523		
N =	231			242		

Note: Significant at 5%.

choice CVM. Our purpose in this paper was to estimate the WTP under the assumption that respondents are not always certain regarding their response to the elicited bid for WTP.

By applying fuzzy theory in CVM, we estimated the WTP for the preservation of Asiatic Black Bear which is critically endangered in

Korea. The estimated WTP was about 90 US dollars per household with 78 percent of confidence level. This implies that the advantage of using fuzzy theory could be found in obtaining a confidence level for the estimated WTP if we accept the presence of preference uncertainty in using CVM.

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〈Web-Site〉

1. International Union for Conservation of Nature and Natural Resources (www.iucn.org).

2. Korea National Statistical Office (www.nso.go.kr)

3. Ministry of Environment, Republic of Korea (www.me.go.kr).

4. The Asiatic Black Bear Management Team, Republic of Korea (www.npa.or.kr/bear).

퍼지이론을 이용한 지불의사액의 추정

이성태 · 이광석

본 연구는 이산선택 조건부가치측정법에 내재되어 있는 응답자의 선호의 불확실성 문제를 퍼지이론을 통해 해결하려 한 것으로, 멸종위기에 처해 있는 한국산 토종반달곰의 보존에 대한 지불의사액을 추정하는 분석과정에 퍼지소속도 함수를 적용하였다. 퍼지소속도 이론은 애매모호한 상황의 불명확성을 추정하는 방법론으로, 이를 조건부가치측정법에 적용하면 해당 환경재에 대한 지불의사액과 응답자들의 진술에 대한 확신도를 동시에 도출해낼 수 있다.

본 연구를 위해 우리나라 7대 광역시에 거주하는 성인남녀 500명을 대상으로 설문조사를 시행하였으며 양분선택형 조건부가치측정법이 사용되었다. 한국산 토종반달곰 보존에 대한 지불의사액은 가구당 월 9,090원으로 계산되었으며 퍼지소속도함수로 계산된 응답의 확신도는 78%인 것으로 추정되었다.

주제어 : 조건부가치측정법, 퍼지이론, 선호의 불확실성

Measurement of Willingness to Pay
by Using Fuzzy Theory

Sung Tae Lee and Kwangsuck Lee

In this paper, we apply fuzzy theory in a discrete choice Contingent Valuation Method(CVM) in order for dealing preference uncertainty problem. Fuzzy membership function is used in an empirical analysis to estimate the willingness-to-pay(WTP) for the preservation of the endangered Asiatic Black Bear in Korea. The estimated WTP was about 9,090 Korea Won per household with 78 percent of confidence level. The advantage of applying fuzzy theory in the valuation method could be found in its ability to measure the confidence level of the estimated WTP.

Keywords : CVM, Fuzzy Theory, Preference Uncertainty,
           Asiatic Black Bear