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An almost ideal elicitation contingent valuation method

Abstract

An almost ideal elicitation contingent valuation method (AIECVM), an innovative elicitation design, is constructed to overcome the imperfections of current evaluations of non-market goods and services. This method entails using a triple-bounded discrete choice followed by an open willingness to pay, where the values of offered bids are assigned using the C-optimal design criterion. The weakness of less variety in optimal design bid values can therefore be overcome by increasing the number of choice levels in AIECVM, which makes the bids designed by the optimal design criterion applicable in an actual survey. The most efficient improvement of the related welfare measurement can thus be used as the choice stage moves forward. Data from a sample of 700 households evaluating the benefit of the Black-Faced Spoonbill Protected Area in Taiwan is used for empirical demonstration.

Keywords: c-optimal design, efficiency improvement, four-level elicitation method, incentive compatible.
JEL Classification: C25, C51, Q57.

Introduction

The contingent valuation method (CVM) has been widely used to estimate the values of non-market commodities, especially environmental resources. A survey must be designed to elicit the willingness to pay for (WTP) or willingness to accept (WTA) the goods in a hypothetical market. Bidding game, open-ended choice, and discrete (close-ended) choice are the most commonly used elicitation techniques.

The bidding process has long been used in the literature dealing with behavior in auctions for market goods (Friedman, 1956; Mund, 1960). The strategies and methods for setting optimal bid prices have been studied consistently since then in papers such as Brisset and Naegelen (2006) and Rasmusen (2006). Davis (1963), however, pioneered the use of a bidding game for non-market goods. To obtain the proper bid values of non-market goods and services, the game is typically designed so that the first step is to offer the respondent a starting bid. If the starting bid receives a positive response, the bid amount is adjusted upward until an amount is rejected. By contrast, if the starting bid receives a negative response, the bid amount is revised downward until a positive response is elicited. The highest bid with a positive response is the respondent's WTP or WTA (Randall et al., 1974).

This bidding game for non-market goods uses an iterative process that allows the respondent to easily identify and evaluate his WTP or WTA (Boyle and Bishop, 1988). The advantage of this process is that it is similar to an auction, so it is not difficult for the respondents to understand. However, the weakness of the approach is that there are no rules for setting the upward and downward increments between bids or the number of bid iterations.

At the other end of the spectrum, survey respondents can be invited to state a specific dollar amount in an open-ended format (Hammack and Brown, 1974). The value of this technique is its simplicity for empirical estimation relative to data collected from a bidding game. However, asking the respondents to reveal their WTP or WTA directly may be impossible or inapplicable, and therefore many more non-responses are observed relative to other methods (Arrow et al., 1993). Furthermore, open-ended questions do not provide enough information to enable respondents to thoroughly determine the value of the resource (Anderson and Bishop, 1986).

Discrete choice, the simplest form of single-bounded dichotomous choice, was initially used by Bishop and Heberlein (1986) and first theorized by Hanemann (1984). This method became even more popular when the NOAA panel suggested guidelines after the EXXON *Valdez* oil spill in Alaska in 1989 (Arrow et al., 1993). This format offers respondents an amount and asks them to vote for (yes) or against (no) the item being valued. The obvious advantage of dichotomous choice is that the process is similar to shopping in a marketplace. At the same time, the format is proven to have the potential to reduce strategic bias to the minimum (Hoehn and Randall, 1987). One of the most recent empirical studies concerned with WTP and WTA by applying single-bounded CVM is done by Petrolia and Kim (2011).

The inescapable disadvantage of the discrete choice method is that much less information is collected as compared to numerical responses obtained from the bidding game or open-ended formats (Boyle and Bishop, 1988). As such, Carson et al. (1986) expanded the idea of simple yes-no dichotomous choice to a two-level discrete choice called double-bounded dichotomous choice. More information is collected, resulting in relatively efficient welfare measurements (Hanemann et al., 1991; Adaman et al., 2010). One disadvantage of analyzing responses to a discrete survey is that relatively delicate and complicated statistical techniques are necessary.

As described above, the related welfare measurements gain efficiency as the level of dichotomous choice is expanded from single or double to higher levels. Scarpa and Bateman (2000) and Bateman et al. (2001) have shown this in empirical analyses of a triple-bounded dichotomous choice. The efficiency improves at a decreasing rate as the level of dichotomous choice moves from single to double and further to triple-bounded (Scarpa and Bateman, 2000).

The above discussion implies that more efficiency will be gained as more stages of dichotomous choices are added, although the increments of efficiency improvements are decreasing. Therefore, the question confronting us now is whether it is worthwhile and manageable to continue to expand the levels of discrete choice in exchange for additional efficiency improvements in the related welfare measurements, or could the merits of the choice technique be retained while compensating for the possible loss of information with an open revelation follow-up survey?

It seems reasonable to search for an elicitation method that combines the advantages of both the dichotomous choices and the open-ended technique (Ojeda et al., 2008; Brouwer et al., 2009; Awad and Hollander, 2010). Double-bounded discrete choice followed by continuous open revelation, called the double-bounded with open-ended follow-up elicitation method, has been employed by Tisdell and Wilson (2001) and DeShazo (2002) in some empirical surveys. However, these studies use only the final open revelation WTP as the welfare measurement. The advantages of this format have not been developed to its utmost.

Alternatively, this process could use a format nominally similar to bidding game. To advance the current use and design of this elicitation format, the set of bids are formed by the C-optimal criterion. The most efficient improvement of the related welfare measurement will then be constrained to its optimum as the choice stages move forward.

An elicitation method in the form of a triple-bounded discrete choice followed by a continuous open willingness-to-pay revelation, called an almost ideal elicitation contingent valuation method (AIECVM), will be designed in this study to achieve the goals described above. Data from a sample of 700 households evaluating the benefit of the Black-Faced Spoonbill Protected Area in Taiwan is used to conduct the empirical demonstration.

1. Framework of AIECVM

1.1. Bid design in AIECVM. Previous theoretical optimal bid designs have assumed that there are only one or two bid prices in the single-bounded or double-bounded choice formats (Kanninen, 1993a; Minkin, 1987; Alberini, 1995). The lack of variety of bid values usually makes the estimation of a mean WTP inapplicable. On the other hand, the values used in the actual surveys for single-bounded, double-bounded, and triple-bounded discrete choice studies are mostly multiple bids. Although these bids are empirically applicable, they do not improve efficiency of the related welfare measurements (Kanninen, 1993b). Additionally, multiple bids generally follow the symmetric principle. That is, if one bid value is higher than the mean WTP, there must be another bid value that is less than the mean WTP (Cooper, 1994; McLeod and Bergland, 1999).

As a result, following the optimal design principle to determine the offered bids and make them apposite to empirical application is the major task in creating an ideal elicitation approach. Based on previous research, a decision process revealed through a triple-bounded discrete choice followed by a continuous open willingness-to-pay is then constructed. The dichotomous choice is expanded to three levels where one bid set consists of seven different bid values generated by an optimal design. The weakness optimal design bid values have less variety that can therefore be overcome by increasing bid levels, and those bid values can thus be used in an actual survey.

In the elicitation framework of AIECVM, the initial bid A_i is offered, and the respondent *i* decides whether to pay this bid or not. If the first response is ‘yes’, then a higher second bid A_i^U is offered. If not, a lower second bid A_i^L is offered. The third bid depends upon the former response path. A higher third bid A_i^{UU} is presented to those who had answered ‘yes’ twice. In contrast, a lower third bid A_i^{LL} is given to those who had answered ‘no’ twice. A third bid between A_i^U and A_i^L, A_i^{UL} or A_i^{LU}, is offered to respondents who replied ‘yes’ and then ‘no’ or ‘no’ and then ‘yes’ respectively.

Under this elicitation structure, it is expected that more respondents will be encouraged to reveal their possible willingness-to-pay range in the last open-ended request following the three-stage dichotomous choice. As a result, all possible final willingness-to-pay revelation outcomes should fall in the following eight intervals $(-\infty, A_i^{LL})$, $[A_i^{LL}, A_i^L)$, $[A_i^L, A_i^{LU})$, $[A_i^{LU}, A_i)$, $[A_i, A_i^{UL})$, $[A_i^{UL}, A_i^U)$, $[A_i^U, A_i^{UU})$, and $[A_i^{UU}, \infty)$.

The order of the above seven bids has the relationship $A_i^{LL} < A_i^L < A_i^{LU} < A_i < A_i^{UL} < A_i^U < A_i^{UU}$, but assigning exact values for each bid is essential. AIECVM follows the optimal design principle to determine these offered bids. The purpose of optimal design for dichotomous choice is to design the bid values so that the fixed sample size provides the most possible information about the response functions parameters or mean WTP. Among various popularly used optimal design criteria, the C-optimal design is the one that minimizes the variance of mean WTP (Aigner, 1979). When the goal is to estimate the mean value of environmental resources, obtaining an efficient mean WTP is critical. In addition, the bid amounts in an optimal design are also influenced by different model settings, such as a logit or probit model (Wu, 1998; Minkin, 1987; Kanninen, 1993a; Alberini, 1995).

In order to compare the efficiency performance of the final open WTP following three dichotomous choice stages, the expenditure difference interpretation is adopted to specify the response function[1]. If individual i initially has an expenditure level of E_i^0 with level of environmental goods at Q^0, the utility level is $U_i^0 = U_i(Q^0, E_i^0)$. When the level of environmental goods increases to level Q^+, some expenditure is required to remain at the initial utility level U_i^0. The maximum amount that the individual i will pay is Hicksian compensating surplus, denoted as WTP_i^C. The compensating surplus can be represented as:

$$U^0(Q^0,\ E_i^0) = U^0(Q^+,\ E_i^0 - WTP_i^C)\cdot \tag{1}$$

The willingness-to-pay of respondent i, designated as Y_i, is unobservable, and it is assumed that this amount is the sum of the deterministic term WTP_i^C, denoted Δe_i, and a stochastic term $\Delta\varepsilon_i$. That is,

$$Y_i = \Delta e_i + \Delta\varepsilon_i, \tag{2}$$

where $\Delta\varepsilon_i$ follows a symmetric probability density function with $E(\Delta\varepsilon_i) = 0$ and $V(\Delta\varepsilon_i) = \sigma^2$.

Because willingness-to-pay Y_i is unobservable, indicators I_i^1, I_i^2, and I_i^3 are the variables used to represent the first, second, and third dichotomous responses for the respondents. Thus, the eight different possible choice combinations are as follows:

$$\left(I_i^1, I_i^2, I_i^3\right) = \begin{cases} (1,1,1), \text{ when } Yi \geq Ai,\ Yi \geq A_i^U, \text{ and } Yi \geq A_i^{UU} \\ (1,1,0), \text{ when } Yi \geq Ai,\ Yi \geq A_i^U, \text{ and } Yi < A_i^{UU} \\ (1,0,1), \text{ when } Yi \geq Ai,\ Yi < A_i^U, \text{ and } Yi \geq A_i^{UL} \\ (1,0,0), \text{ when } Yi \geq Ai,\ Yi < A_i^U, \text{ and } Yi < A_i^{UL} \\ (0,1,1), \text{ when } Yi < Ai,\ Yi \geq A_i^L, \text{ and } Yi \geq A_i^{LU} \\ (0,1,0), \text{ when } Yi < Ai,\ Yi \geq A_i^L, \text{ and } Yi < A_i^{LU} \\ (0,0,1), \text{ when } Yi < Ai,\ Yi < A_i^L, \text{ and } Yi \geq A_i^{LL} \\ (0,0,0), \text{ when } Yi < Ai,\ Yi < A_i^L, \text{ and } Yi < A_i^{LL} \end{cases}. \tag{3}$$

The probability of a positive response to the first, second, and third offered price is computed as:

$$\operatorname{Prob}\left(I_i^1 = 1, I_i^2 = 1, I_i^3 = 1\right) = \operatorname{Prob}\left(Y_i \geq A_i, Y_i \geq A_i^U, \text{and } Y_i \geq A_i^{UU}\right) = F_\varepsilon\left(\frac{\Delta e_i - A_i^{UU}}{\sigma}\right), \tag{4}$$

where $F_\varepsilon(\cdot)$ is the cumulative distribution function with mean zero and standard deviation one. The probabilities of the other seven choice combinations can be computed accordingly.

Because the values of respondents' socio-demographic variables are not available prior to the actual survey, the optimal design does not include these as regressors (Alberini, 1995). Therefore, only mean WTP, denoted $\Delta e_i = \mu$, is used for the response function. The likelihood function can be written as:

$$\begin{aligned} \ln L^T = \sum_{i=1}^{N} [& I_i^1 I_i^2 I_i^3 \ln F_i^{UU} + I_i^1 I_i^2 (1 - I_i^3) \ln(F_i^U - F_i^{UU}) + I_i^1 (1 - I_i^2) I_i^3 \ln(F_i^{UL} - F_i^U) + \\ & + I_i^1 (1 - I_i^2)(1 - I_i^3) \ln(F_i - F_i^{UL}) + (1 - I_i^1) I_i^2 I_i^3 \ln(F_i^{LU} - F_i) + (1 - I_i^1) I_i^2 (1 - I_i^3) \ln(F_i^L - \\ & - F_i^{LU}) + (1 - I_i^1)(1 - I_i^2) I_i^3 \ln(F_i^{LL} - F_i^L) + (1 - I_i^1)(1 - I_i^2)(1 - I_i^3) \ln(1 - F_i^{LL})], \end{aligned} \tag{5}$$

[1] The duality of the utility difference and the expenditure difference interpretation has been theoretically proven and empirically verified by McConnel (1990) and Wu and Hsieh (1996).

where $F_i^{UU} = F_\varepsilon\left(d_i^{UU}\right)$, $F_i^{U} = F_\varepsilon\left(d_i^{U}\right)$, $F_i^{UL} = F_\varepsilon\left(d_i^{UL}\right)$, $F_i = F_\varepsilon\left(d_i\right)$, $F_i^{LU} = F_\varepsilon\left(d_i^{LU}\right)$, $F_i^{L} = F_\varepsilon\left(d_i^{L}\right)$, $F_i^{LL} = F_\varepsilon\left(d_i^{LL}\right)$, and $d_i^{UU} = \left(\mu - A_i^{UU}\right)/\sigma$, $d_i^{UL} = \left(\mu - A_i^{UL}\right)/\sigma$, $d_i = \left(\mu - A_i\right)/\sigma$, $d_i^{LU} = \left(\mu - A_i^{LU}\right)/\sigma$, $d_i^{L} = \left(\mu - A_i^{L}\right)/\sigma$, $d_i^{LL} = \left(\mu - A_i^{LL}\right)/\sigma$, and $0 < F_i^{UU} < F_i^{U} < F_i^{UL} < F_i < F_i^{LU} < F_i^{L} < F_i^{LL} < 1$ holds.

The estimated μ and σ can be computed from the first-order conditions of equation (5). The information matrix is as follows:

$$\ln f^T(\beta,\sigma) = -E\left[H^T\right] = \begin{bmatrix} -E\left[\dfrac{\partial^2 \ln L^2}{\partial\mu^2}\right] & -E\left[\dfrac{\partial^2 \ln L^T}{\partial\mu\partial\sigma}\right] \\ -E\left[\dfrac{\partial^2 \ln L^T}{\partial\sigma\partial\mu}\right] & -E\dfrac{\partial^2 \ln L^T}{(\partial\sigma)^2} \end{bmatrix}, \tag{6}$$

where H^T in equation (6) is the Hessian matrix and the elements in the information matrix are computed as in equations (7)-(9):

$$-E\left[\frac{\partial^2 \ln L^T}{\partial\mu^2}\right] = \sum_{i=1}^{N}\left[\frac{\left(f_i^{UU}\right)^2}{F_i^{UU}} + \frac{\left(f_i^{U}-f_i^{UU}\right)^2}{F_i^{U}-F_i^{UU}} + \frac{\left(f_i^{UL}-f_i^{U}\right)^2}{F_i^{UL}-F_i^{U}} + \frac{\left(f_i-f_i^{UL}\right)^2}{F_i-F_i^{UL}} + \frac{\left(f_i^{LU}-f_i\right)^2}{F_i^{LU}-F_i} + \frac{\left(f_i^{L}-f_i^{LU}\right)^2}{F_i^{L}-F_i^{LU}} + \frac{\left(f_i^{LL}-f_i^{L}\right)^2}{F_i^{LL}-F_i^{L}} + \frac{\left(f_i^{LL}\right)^2}{1-F_i^{LL}}\right] \times \frac{1}{\sigma^2}, \tag{7}$$

$$-E\left[\frac{\partial^2 \ln L^T}{\partial\mu\partial\sigma}\right] = -E\left[\frac{\partial^2 \ln L^T}{\partial\mu\partial\sigma}\right] =\leq$$

$$\leq \sum_{i=1}^{N}\left[\frac{\left(f_i^{UU}\right)^2 d_i^{UU}}{F_i^{UU}} + \frac{\left(f_i^{U}-f_i^{UU}\right)\left(f_i^{U}d_i^{U}-f_i^{UU}d_i^{UU}\right)}{F_i^{U}-F_i^{UU}} + \frac{\left(f_i^{UL}-f_i^{U}\right)\left(f_i^{UL}d_i^{UL}-f_i^{U}d_i^{U}\right)}{F_i^{UL}-F_i^{U}} + \right.$$

$$+\frac{\left(f_i-f_i^{UL}\right)\left(f_i d_i - f_i^{UL}d_i^{UL}\right)}{F_i-F_i^{UU}} + \frac{\left(f_i^{LU}-f_i\right)\left(f_i^{LU}d_i^{LU}-f_i d_i\right)}{F_i^{LU}-F_i} +$$

$$\left. +\frac{\left(f_i^{L}-f_i^{LU}\right)\left(f_i^{L}d_i^{L}-f_i^{UL}d_i^{UL}\right)}{F_i^{L}-F_i^{LU}} + \frac{\left(f_i^{LL}-f_i^{L}\right)\left(f_i^{LL}d_i^{LL}-f_i^{L}d_i^{L}\right)}{F_i^{LL}-F_i^{L}} + \frac{\left(f_i^{LL}\right)^2 d_i^{LL}}{1-F_i^{LL}}\right] \times \frac{1}{\sigma^2}, \tag{8}$$

$$-E\left[\frac{\partial^2 \ln L^T}{\partial\sigma^2}\right] = \sum_{i=1}^{N}\left[\frac{\left(f_i^{UU}d_i^{U}\right)^2}{F_i^{UU}} + \frac{\left(f_i^{U}-f_i^{UU}\right)^2}{F_i^{U}-F_i^{UU}} + \frac{\left(f_i^{UL}f_i^{UL}-f_i^{U}d_i^{U}\right)^2}{F_i^{UL}-F_i^{U}} + \frac{\left(f_i d_i - f_i^{UL}d_i^{UL}\right)^2}{F_i-F_i^{UL}} + \right.$$

$$\left. +\frac{\left(f_i^{LU}d_i^{LU}-f_i d_i\right)}{F_i^{LU}-F_i^{L}} + \frac{\left(f_i^{L}d_i^{L}-f_i^{LU}d_i^{LU}\right)}{F_i^{L}-F_i^{LU}} + \frac{\left(f_i^{LL}d_i^{LL}-f_i^{L}d_i^{L}\right)^2}{F_i^{LL}-F_i^{L}} + \frac{\left(f_i^{LL}d_i^{LL}\right)^2}{1-F_i^{LL}}\right] \times \frac{1}{\sigma^2}, \tag{9}$$

where $f_i^{UU} = f_\varepsilon\left(d_i^{UU}\right)$, $f_i^{U} = f_\varepsilon\left(d_i^{U}\right)$, $f_i^{UL} = f_\varepsilon\left(d_i^{UL}\right)$, $f_i = f_\varepsilon\left(d_i\right)$, $f_i^{LU} = f_\varepsilon\left(d_i^{LU}\right)$, $f_i^{L} = f_\varepsilon\left(d_i^{L}\right)$, and $f_i^{LL} = f_\varepsilon\left(d_i^{LL}\right)$, are the probability density functions corresponding to F_i^{UU}, F_i^{U} F_i^{UL}, F_i, F_i^{LU}, F_i^{L}, and F_i^{LL}.

Based on the studies done by Wu (1998) and by Kanninen (1993a), it is known that the optimal bid values in the third stage, γ, should be set to represent the probability that respondent i's WTP Y_i lies between the optimal bid values in the second stage and the third stage as long as certain conditions hold. These conditions are (a) the error term $\Delta\varepsilon_i$ follows a logistic distribution; (b) each respondent is offered the same bid set; (c) the bid value in the first stage is mean WTP, i.e. $A_i = \mu$; and (d) the bid values in the second stage are:

$$A_i^{U} = \mu + \left(\sqrt{3}\ln 3/\pi\right)\sigma \text{ and } A_i^{L} = \mu - \left(\sqrt{3}\ln 3/\pi\right)\sigma.$$

That is,

$$F_i^{U} - F_i^{UU} = F_i^{UL} - F_i^{U} = F_i^{L} - F_i^{LU} = F_i^{LL} - F_i^{L} = \gamma$$

and $0 < \gamma < 0.25$.

We can thus establish the following relations:

$$F_i^{UU} = F_\varepsilon\left(d_i^{UU}\right) = 0.25 + \gamma, \quad (10a)$$

$$F_i^{U} = F_\varepsilon\left(d_i^{U}\right) = 0.25, \quad (10b)$$

$$F_i^{UL} = F_\varepsilon\left(d_i^{UL}\right) = 0.25 + \gamma, \quad (10c)$$

$$F_i = F_\varepsilon\left(d_i\right) = 0.25 + \gamma, \quad (10d)$$

$$F_i^{LU} = F_\varepsilon\left(d_i^{LU}\right) = 0.75 - \gamma, \quad (10e)$$

$$F_i^{L} = F_\varepsilon\left(d_i^{L}\right) = 0.75, \quad (10f)$$

$$F_i^{LL} = F_\varepsilon\left(d_i^{LL}\right) = 0.75 - \gamma, \quad (10g)$$

where $F_\varepsilon(.)$ is the cumulative distribution function for the logistic distribution with zero mean and standard deviation of one. According to Johnson and Kotz (1970), the $F_\varepsilon(.)$ can be showed as in (10h).

$$\Phi(a) = 1/1 + \exp\left(-\left(\pi/\sqrt{3}\right)\times a\right), \forall a \in R \quad (10h)$$

As a result, the following equations (11a)-(11g) hold:

$$d_i^{UU} = \frac{\sqrt{3}}{\pi}\times[\ln(0.25-\gamma) - \ln(0.75+\gamma)], \quad (11.1)$$

$$d_i^{U} = \frac{\sqrt{3}}{\pi}\times \ln 3, \quad (11.2)$$

$$d_i^{UL} = \frac{\sqrt{3}}{\pi}\times[\ln(0.25+\gamma) - \ln(0.75-\gamma)], \quad (11.3)$$

$$d_i = 0, \quad (11.4)$$

$$d_i^{LU} = \frac{\sqrt{3}}{\pi}\times\left[\ln\left(0.75-\gamma\right) - \ln\left(0.25+\gamma\right)\right], \quad (11.5)$$

$$d_i^{L} = \frac{\sqrt{3}}{\pi}\times \ln 3, \quad (11.6)$$

$$d_i^{LL} = \frac{\sqrt{3}}{\pi}\times\left[\ln\left(0.75+\gamma\right) - \ln\left(0.25-\gamma\right)\right]. \quad (11.7)$$

If, furthermore, the distribution is logistic with zero mean and standard deviation of one, then the following Lemma holds.

Lemma. If $\varphi(.)$ and $\Phi(.)$ are the probability density functions and the cumulative distribution functions respectively for a logistic distribution with mean zero and standard deviation one, then:

1. For any number *a*, if $a \notin R$, there exists:

$$\varphi(a) = \frac{\sqrt{3}}{\pi}\times\Phi(a)[1-\Phi(a)].$$

2. For any numbers *a* and *b*, if $a,b \in R$ and $a < b$ then there exists:

$$\varphi(b) - \varphi(a) = \frac{\pi}{\sqrt{3}}\left[\Phi(b) - \Phi(a)\right][1-\Phi(b)-\Phi(a)].$$

According to equations (10a)-(10g) and the Lemma, elements of the Hessian matrix in equations (7)-(9) and the variance of mean WTP can be simplified as follows:

$$-E\left[\frac{\partial^2 \ln L^T}{\partial\mu^2}\right] = \frac{\pi^2}{3}\times\left(-\gamma^2 + 0.25\gamma + 0.3125\right)\times\frac{N}{\partial^2}, \quad (12)$$

$$-E\left[\frac{\partial^2 \ln L^T}{\partial\mu\partial\sigma}\right] = E\left[\frac{\partial^2 \ln L^T}{\partial\sigma\partial\mu}\right] = 0. \quad (13)$$

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^T}{\left(\partial\sigma\right)^2}\right] = \left\{\frac{1}{2\gamma}\left(0.25-\gamma\right)\left(0.75+\gamma\right)^2\times\left[\ln\left(0.25-\gamma\right) - \ln\left(0.75+\gamma\right)^2\right]\times\right.$$

$$\times 0,25\times 0.75\times\ln 3\times\left[\ln\left(0.25-\gamma\right) - \ln\left(0.75+\gamma\right)\right] + \frac{4}{\gamma}\times\left(0,25\right)^2\times\left(0,75\right)^2\times\left(\ln 3\right)^2 + \frac{4}{\gamma}\left(0.25+\gamma\right)\times$$

$$\times\left(0.75-\gamma\right)\times 0.25\times 0.75\times\ln 3\times\left[\ln\left(0.25+\gamma\right) - \ln\left(0.75-\gamma\right)\right] +$$

$$\left. + \frac{1}{2\gamma\left(0.25-\gamma\right)}\times\left(0.25+\gamma\right)^2\times\left(0.75-\gamma\right)^2\times\left[\ln\left(0.25+\gamma\right) - \ln\left(\ln 3\right)\left(0.75-\gamma\right)^2\right]\right\}\times\frac{N}{\sigma^2}. \quad (14)$$

$$Var(\hat{\mu}_T) = -\mathrm{E}\left[\frac{\partial^2 \ln L^T}{\partial\mu^2}\right]^{-1} = \frac{3}{\pi^2}\left(-\gamma^2 + 0.25\gamma + 0.3125\right)^{-1}\times\frac{\sigma^2}{N}. \quad (15)$$

The C-optimal design is to minimize the variance of mean WTP, so the minimization of equation (16) must be solved:

$$\min_{0<\gamma<0.25} \quad Var(\hat{\mu}_T) = \frac{3}{\pi^2}\left(-\gamma^2 + 0.25\gamma + 0.3125\right)^{-1}\times\frac{\sigma^2}{N}. \quad (16)$$

The minumum variance occurs when $\gamma = 0.125$. Substituting $\gamma = 0.125$ into equations (11a)-(11g), $d_i^{UU} = -\sqrt{3}\ln 7/\pi$, $d_i^{UL} = -\sqrt{3}(\ln 5 - \ln 3)/\pi$, $d_i^{LU} = \sqrt{3}(\ln 5 - \ln 3)/\pi$, and $d_i^{LL} = \sqrt{3}\ln 7/\pi$ are obtained. Thus, the optimal bids for the third stage are:

$A_i^{UU} = \mu + \left(\sqrt{3}\ln 7/\pi\right) \times \sigma$,

$A_i^{UL} = \mu + \left(\sqrt{3}(\ln 5 - \ln 3)/\pi\right) \times \sigma$,

$A_i^{LU} = \mu - \left(\sqrt{3}(\ln 5 - \ln 3)/\pi\right) \times \sigma$, and

$A_i^{LL} = \mu - \sqrt{3}\ln 7/\pi \times \sigma$.

Therefore, the seven bids offered in AIECVM have the relationship shown in Table 1.

1.2. Efficiency change throughout elicitation stages in AIECVM. In the first three-stage dichotomous choice framework of AIECVM, the choice results from the elements of the information matrix are:

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^S}{\partial \mu^2}\right] = \sum_{i=1}^{N}\left[\frac{f_i^2}{F_i} + \frac{f_i^2}{1-F_i}\right] \times \frac{1}{\sigma^2}, \tag{17}$$

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^S}{\partial \mu \partial \sigma}\right] = -\mathrm{E}\left[\frac{\partial^2 \ln L^S}{\partial \sigma \partial \mu}\right] = -\sum_{i=1}^{N}\left[\frac{f_i^2}{F_i} + \frac{f_i^2}{1-F_i}\right] \times d \times \frac{1}{\sigma^2}, \tag{18}$$

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^S}{(\partial \sigma)^2}\right] = \sum_{i=1}^{N}\left[\frac{f_i^2}{F_i} + \frac{f_i^2}{1-F_i}\right] \times \frac{d_i^2}{\sigma^2} \tag{19}$$

Table 1. The formula of bid design for AIECVM

Bid	Formula[a]
A_i^{LL}	$\mu - \frac{\sqrt{3}\ln 7}{\pi} \times \sigma$
A_i^{L}	$\mu - \frac{\sqrt{3}\ln 3}{\pi} \times \sigma$
A_i^{LU}	$\mu - \frac{\sqrt{3}(\ln 5 - \ln 3)}{\pi} \times \sigma$
A_i	μ
A_i^{UL}	$\mu + \frac{\sqrt{3}(\ln 5 - \ln 3)}{\pi} \times \sigma$
A_i^{U}	$\mu + \frac{\sqrt{3}\ln 3}{\pi} \times \sigma$
A_i^{UU}	$\mu + \frac{\sqrt{3}\ln 7}{\pi} \times \sigma$

Note a: μ is the mean WTP and σ is the standard deviation of random term $\Delta\varepsilon_i$.

Because only one set of offered prices is designed in AIECVM, every respondent is offered the same price. Moreover, according to the above Lemma, the information matrix and the variance of mean WTP can be inferred as in equations (20)-(21):

$$Inf^S(\mu, \sigma) = \begin{bmatrix} 0.25 \times \frac{\pi^2}{3} \times \frac{N}{\sigma^2} & 0 \\ 0 & 0 \end{bmatrix}, \tag{20}$$

$$Var(\hat{\mu}_S) = 4 \times \frac{3}{\pi^2} \times \frac{\sigma^2}{N}. \tag{21}$$

Moving to the second stage of the discrete choice, when respondent i is presented with the first offered price $\$A_i$ followed by a higher or lower second offered price $\$A_i^U$ or $\$A_i^L$, there exist four different choice combinations under these three price levels. The estimated μ and σ can be computed accordingly.

The elements of the information matrix can be computed specifically as (22)-(24):

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^D}{\partial \mu^2}\right] = \sum_{i=1}^{N}\left[\frac{\left(f_i^U\right)^2}{F_i^U} + \frac{\left(f_i - f_i^U\right)^2}{F_i - F_i^U} + \frac{\left(f_i^L - f_i\right)^2}{F_i^L - F_i} + \frac{\left(f_i^L\right)^2}{1 - F_i^L}\right] \times \frac{1}{\sigma^2}, \tag{22}$$

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^D}{\partial\mu\partial\sigma}\right]=\mathrm{E}\left[\frac{\partial^2 \ln L^D}{\partial\sigma\partial\mu}\right]=$$
$$=-\sum_{i=1}^{N}\left[\frac{\left(f_i^U\right)^2 d_i^U}{F_i^U}+\frac{\left(f_i-f_i^U\right)\left(f_i d_i-f_i^U d_i^U\right)}{F_i-F_i^U}+\frac{\left(f_i^L-f_i\right)\left(f_i^L d_i^L-f_i d_i\right)}{F_i-F_i^U}+\frac{\left(f_i^L\right)^2 d_i^L}{1-F_i^L}\right]\times\frac{1}{\sigma^2}, \tag{23}$$

$$-\mathrm{E}\left[\frac{\partial^2 \ln L^D}{\left(\partial\sigma\right)^2}\right]=\sum_{i=1}^{N}\left[\frac{\left(f_i^U d_i^U\right)^2}{F_i^U}+\frac{\left(f_i d_i-f_i^U\right)\left(f_i^L d_i^L-f_i d_i\right)^2}{F_i^L-F_i}++\frac{\left(f_i^L d_i^L\right)^2}{1-F_i^L}\right]\times\frac{1}{\sigma^2}, \tag{24}$$

when $d_i^U=-\sqrt{3}/\pi\times\ln 3$, $d_i=0$, and $d_i^L=\sqrt{3}/\pi\times\ln 3$, the corresponding $F_i^U=0.25$, $F_i=0.5$, and $F_i^L=0.75$ are obtained. According to these results and the Lemma, the information matrix and the variance of mean WTP from the second stage of the discrete choice are shown in equations (25)-(26):

$$Inf^D\left(\mu,\sigma\right)=\begin{bmatrix}0.3125\times\frac{\pi^2}{3}\times\frac{N}{\sigma^2} & 0\\ 0 & 0.6789\times\frac{N}{\sigma^2}\end{bmatrix}, \tag{25}$$

$$Var(\hat{\mu}_D)=3.2\times\frac{\sigma^2}{N}\times\frac{3}{\pi^2}\cdot \tag{26}$$

When the respondent moves to the third stage dichotomous choice, three choice indicators I_i^1, I_i^2, and I_i^3 are used to represent his first, second, and third responses. Substituting the optimal $\gamma=0.125$ into the elements of information matrix, the information matrix and the variance of mean WTP are then computed as follows:

$$Inf^T\left(\mu,\sigma\right)=\begin{bmatrix}0.3281\times\frac{\pi^2}{3}\times\frac{N}{\sigma^2} & 0\\ 0 & 1.0739\times\frac{N}{\sigma^2}\end{bmatrix}, \tag{27}$$

$$Var(\hat{\mu}_T)=3.0476\times\frac{\sigma^2}{N}\times\frac{3}{\pi^2}\cdot \tag{28}$$

It is expected that more respondents will be encouraged to reveal their willingness-to-pay range in the final open elicitation process because of the three stages of the discrete choice process. In order to compare to the analyses of the discrete choice, the method of maximum likelihood estimation is performed for data of the final willingness-to-pay amount.

Assuming that the final willingness-to-pay of respondent i is Y_i then the probability density function is shown as:

$$f\left(Y_i\right)=\left(\frac{\pi}{\sqrt{3}\,\sigma}\right)\times\frac{e^{-q_i}}{(1+e^{-q_i})^2}, \tag{29}$$

where $q_i=\frac{\pi}{\sqrt{3}\,\sigma}\times\left(Y_i-\mu\right)$. If N_1 respondents are able to determine their WTP even without a dichotomous choice process and if the discrete choice process allows the remaining N-N_1 respondents to determine their WTP, then the joint probability density function for all N respondents will be in the form of:

$$f\left(Y_1,Y_2,\cdots\cdots,Y_N\right)=f\left(Y_1\right)f\left(Y_2\right)\cdots f\left(Y_{N_1}\right)\times f\left(Y_{N_1+1}\right)f\left(Y_{N_1+2}\right)\cdots f\left(Y_N\right)=$$
$$=\left(\frac{\pi}{\sqrt{3}\,\sigma}\right)^{N_1}\times\frac{e^{-\sum_{i=1}^{N_1}q_i}}{\prod_{i=1}^{N_1}(1+e^{-q_i})^2}\times\left(\frac{\pi}{\sqrt{3}\,\sigma}\right)^{N-N_1}\times\frac{e^{-\sum_{i=N_1+1}^{N}q_i}}{\prod_{i=N_1+1}^{N}(1+e^{-q_i})^2}. \tag{30}$$

With the aid of the first three stages of the discrete choice process proposed above, it is expected that more respondents will answer the open-ended question through the triple-bounded with open-ended follow-up elicitation decision process. The likelihood function at this stage can thus be simplified as:

$$\ln L^O = N \ln \frac{\pi}{\sqrt{3}} - N \ln \sigma - \sum_{i=1}^{N} q_i - 2\sum_{i=1}^{N} \ln(1+e^{-q_i}). \quad (31)$$

The estimated parameters μ and σ can be computed from the first-order conditions of equation (31), and the elements of the information matrix and variance of the mean WTP can be computed specifically as:

$$Inf^O(\mu,\sigma) = \begin{bmatrix} 0.3333 \times \frac{\pi^2}{3} \times \frac{N}{\sigma^2} & 0 \\ 0 & 1.4300 \times \frac{N}{\sigma^2} \end{bmatrix}. \quad (32)$$

$$Var(\hat{\mu}_O) = 3 \times \frac{\sigma^2}{N} \times \frac{3}{\pi^2}. \quad (33)$$

Since more respondents are encouraged to reveal their willingness to pay ranges because of the first three stages of the discrete choice process in AIECVM, all the possible final willingness-to-pay revelation outcomes should fall into one of the following eight ranges $(-\infty, A_i^{LL})$, $[A_i^{LL}, A_i^{L})$, $[A_i^{L}, A_i^{LU})$, $[A_i^{LU}, A_i)$, $[A_i, A_i^{UL})$, $[A_i^{UL}, A_i^{U})$, $[A_i^{U}, A_i^{UU})$, and $[A_i^{UU}, \infty)$. Theoretically, the probability of the outcome falling in each range is equal to 12.5%.

The variance of mean WTP is constructed as an efficiency index to identify the efficiency of the benefit measurement in AIECVM. The lower the variance of mean WTP, the higher the efficiency of the welfare measurement is, and vice versa. The variance of mean WTP at every stage of the AIECVM elicitation decision process is computed in equations (21), (26), (28), and (33). The variance decreases as the elicitation procedure moves forward. Furthermore, looking at the rate of efficiency change (i.e., the difference between two variances of consecutive stages), then AIECVM with three stages of discrete choices and one stage of open-ended revelation will make the efficiency improve to its maximum.

2.2. Mean willingness to pay and confidence interval. The mean willingness to pay and the confidence interval estimation of mean willingness to pay under the expenditure difference interpretation can be computed as those determined by least square estimation (Cameron, 1988; Cameron 1991). As a result, given data collected from either the first, second, or third discrete choice or the final open WTP revelation, the mean WTP and the confidence interval for mean WTP can be computed from equations (34) and (35):

$$E(Y) = \hat{\mu}_\Gamma, \Gamma = S, D, T, O, \quad (34)$$

$$CI_{1-\alpha}[E(Y)] = \hat{\mu}_\Gamma \pm t_{\alpha/2}\sqrt{\omega_\Gamma}, \ \Gamma = S, D, T, O, \quad (35)$$

where ω_Γ is the asymptotic variance of $\hat{\mu}_\Gamma$ and $\Gamma = S, D, T, O$ designates data collected from the first, second, third, and final open stages.

Because $(\hat{\mu}_\Gamma, \hat{\sigma}_\Gamma)$ is a maximum likelihood estimator, $Var(\hat{\beta}_\Gamma, \hat{\sigma}_\Gamma)$ will be approximated by the Cramer-Rao lower bound under the consistent and asymptotically efficient estimation of (μ, σ). That is,

$$Var(\hat{\mu}_\Gamma, \hat{\sigma}_\Gamma) = \begin{bmatrix} Var(\hat{\mu}_\Gamma) & Cov(\hat{\mu}_\Gamma, \hat{\sigma}_\Gamma) \\ Cov(\hat{\mu}_\Gamma, \hat{\sigma}_\Gamma)' & Var(\hat{\sigma}_\Gamma) \end{bmatrix} = \left[Inf^\Gamma(\mu,\sigma) \right]^{-1}. \quad (36)$$

According to equation (36), $\omega_\Gamma = Var(\hat{\mu}_\Gamma)$ is obtained.

2. Validation from values of a black-faced spoonbill protected area

2.1. Questionnaire design. The black-faced spoonbill protected area is located at the estuary of the Tsen-Wen River in southern Taiwan, southeast of the coastal township of Chi-Ku in Tainan County. Black-faced spoonbills travel thousands of kilometers to this area from the north of Korea and the northeast of Mainland China. Spoonbill watching at Chi-Ku is a seasonal activity in this area beginning in October and continuing until April of the following year. The presence of spoonbills attracts many tourists to Chi-Ku during the spoonbill season. Tourism may provide a direct or indirect source of income in Chi-Ku. Thus, management of tourism, employment, and conservation in the black-faced spoonbill protected area has been commenced by the government of Tainan County. The direction of this plan emphasizes the interaction between human activities and natural resources at the site and is consistent with the idea of ecotourism.

Currently, when visiting the black-faced spoonbill protected area, tourists stand at three bird-watching kiosks near the protected area and watch the black-faced spoonbills through telescopes prepared by conservation associations or wild bird societies.

However, the locations of the three kiosks are not only too high, but also too far away from the birds. In addition, the black-faced spoonbills are frequently affected and threatened by improper tourist behavior. Furthermore, street vendors accompanying bird-watching activities devastate the area.

Thus, the new project of a multiple function design for the protected area includes an ecological corridor, a visitors' center, a shopping center, and an endemic species research institute. The delineation of the ecological corridor can block visitors from interruption while watching birds and offer close observation of black-faced spoonbills. The visitors' center will provide public education on environmental issues and offer interpretation services for tourists. The shopping center is designed to improve the living conditions of local people by providing employment opportunities. Finally, the endemic species research institute can help to preserve the existence of spoonbills. These facilities will support the ecotourism project and can raise the value of ecotourism, employment, and conservation.

A questionnaire designed in accordance with the idea of tourism, development, and conservation and emphasizing the interaction between human activities and the maintenance of the species is presented to the respondents. The difference between the status quo of the site and the ideal arrangement that the protection area is aiming to achieve is clearly demonstrated in the questionnaire.

Respondents are then required to reveal their willingness-to-pay annual contributions to the black-faced spoonbill conservation fund to acquire the proposed arrangement. Various possible options are recommended for protest responses when no payment is given in the respondent's final open willingness-to-pay. Additional information, such as each respondent's social characteristics, knowledge about the protection area, experience of visiting the area, and other outdoor and various conservation activities are also collected to analyzing their impacts on the willingness to pay.

2.3. Determination of the offered prices and sampling. The rule of optimal bid design stated above is adopted, and seven bid prices are determined as shown in Table 2. The open-ended elicitation method is used in the pretest in order to capture the possible range of willingness-to-pay amounts. Data collected from the pretest are utilized to compute the sample mean and standard deviation of willingness-to-pay to determine the offer prices required in AIECVM discrete choice price levels. A sample of 200 respondents was selected for the pretest survey. The data obtained from the pretest show that the sample mean WTP is about 729.33 NT dollars[1] with a standard deviation of about 674.52 NT dollars. The final optimal offered prices are then 5, 320, 540, 730, 920, 1,140, and 1,450 NT dollars, respectively. This is the set of bid prices used in the first three stages of discrete choice in AIECVM model.

Seven hundred households are then drawn proportionally from the main island of Taiwan according to the distribution of households by city and county. The survey was conducted in January and February 2003 by personal interview. Interviewers were trained before the survey was performed.

Table 2. Bid design used in survey

Bid	Optimal bid amount	Actual offered bid in survey
A^{LL}	5.68	5
A^{L}	320.78	320
A^{LU}	539.36	540
A	729.33	730
A^{UL}	919.30	920
A^{U}	1,137.88	1,140
A^{UU}	1,452.98	1,450

Note: The exchange rate of US dollar to Taiwan New Dollars was about 1:33 in the year of 1999.

2.4. Model specification without respondent's socio-demographic variables. Among the 700 respondents surveyed, 159 were classified as protest respondents for various reasons and 18 were categorized as outliers due to an extremely large final willingness-to-pay, leaving 523 usable observations for further analysis. In order to estimate the mean WTP and realize the influence of the explanatory variables on the WTP, empirical analyses are conducted with and without respondents' socio-demographic variables respectively.

If the purpose of conducting empirical analyses is just to estimate mean WTP and the total value of the black-faced spoonbill protected area, the influence of the socio-demographic variables on WTP can be incorporated into the error term. That is, response function is simply set as $\Delta\ e_i = \mu$. This estimation is not applicable for first-stage estimation because it incorporates only one bid value. The re-

[1] In 2003, the exchange rate between Taiwan New dollars and US dollars was about 35 to 1.

sults of coefficient estimations are presented in Table 3, and the estimated mean WTP and its 95% confidence interval are presented in Table 4. The results indicate that standard deviations of the estimated parameters μ and σ and the variance of mean WTP decrease as the stage increases. Moreover, the ranges of the 95% confidence intervals, represented by a ratio or by a difference, also decrease as choice stage increases. The empirical results are consistent with the theoretical expectations.

Table 3. Results of coefficients estimation for different decision process (without respondent's socio-semographic variables [a,b])

Variable	Decision process		
	Second stage	Third stage	Final stage
μ	594.17** (28.47)	615.14** (27.46)	586.37** (24.40)
σ	652.08** (34.53)	651.17** (27.14)	575.93** (20.75)
Log-L	-713.56	-1078.34	-4052.01

Note: [a]The total usable observations are 523. [b]Numbers in parentheses are standard deviations of estimated coefficients. Numbers with two asterisks indicate the coefficients are significantly different from zero at 1% significant level.

Table 4. Estimated mean WTP and 95% confidence interval of mean WTP (without respondent's socio-demographic variables[a])

Variable	Decision process[b]		
	Second stage	Third stage	Final stage
Mean WTP	594.17	615.14	586.37
Variance of mean WTP	810.30	753.90	595.44
95% confidence interval of mean WTP			
Lower bound	538.37	561.32	538.54
Upperb	649.96	668.95	634.20
Upper bound–Lower bound	111.59	107.63	95.66
Upper bound / Lower bound	1.207	1.192	1.178

Note: [a]The total usable observations are 523. [b]The exchange rate of US dollar to NT dollars was about 1:33 in the year of 1999.

2.5. Model specification with respondent's socio-demographic variables. It is, however, interesting to shed light on the conservation policy using empirical results. As a result, knowing the influence of various socio-demographic variables on final willingness-to-pay is important. Therefore, the explanatory variables and the functional form have to be determined to accomplish this purpose. The explanatory variables include the various socio-demographic variables of the respondents and the variables reflecting knowledge and visitation to the protected area. Table 5 lists all the variables used in the estimation and their mean values and standard deviations.

Table 5. Respondent's various socio-demographic variables used in estimation

Variable name (Unit)	Mean value	Standard deviation	Variable definition
Gender	0.507	0.500	Dummy variable 1 for male, 0 for female
Age (years)	39.245	11.351	Age of respondent
Family (persons)	4.358	2.131	Household size
Edu (years)	13.476	3.237	Years of education of respondent
Income (ten thousand NT $)	94.608	78.435	Household annual income for the year of 2002 from all sources
Knowarea	0.577	0.494	Dummy variable: 1 for the respondent who has known the establishment of black-faced spoonbill protected area; 0 otherwise
See	0.103	0.305	Dummy variable: 1 for the respondent who has ever arrived at the protected area and seen the spoonbill; 0 otherwise
Outdoor	0.438	0.497	Dummy variable: 1 for the respondent who usually go outdoors (once a week at least); 0 otherwise
Green	0.191	0.394	Dummy variable: 1 for the respondent who has been the member of non-profit environmental organization or has attended the conservation activity; 0 otherwise
WTP (NT $)	636.813	556.677	Final open willingness to pay

Note: The total usable observations are 523.

A linear form specified as equation (37) is selected for estimation:

$$\begin{aligned}\Delta e_i &= \beta_0 + \beta_1 \times Gender_i + \beta_2 \times Age_i + \beta_3 \times Family_i + \beta_4 \times Edu_i + \beta_5 \times Income_i + \\ &+ \beta_6 \times Knowarea_i + \beta_7 \times See_i + \beta_8 \times Outdoor_i + \beta_9 \times Green_i.\end{aligned} \quad (37)$$

Let the random term of empirical specification follow the logistic distribution. Since only one set of offered prices is presented to the respondents in the first stage of the elicitation process, the mean willingness-to-pay is not applicable to the first stage. Now the likelihood functions for the second, third, and final stages are equations (38)-(40) respectively:

$$\ln L^D = \sum_{i=1}^{N}\Big[I_i^1 I_i^2 \ln F_i^U + I_i^1\left(1-I_i^2\right)\ln\left(F_i - F_i^U\right) + (1-I_i^1)I_i^2 \ln\left(F_i^L - F_i\right) + \left(1-I_i^1\right)\left(1-I_i^2\right)\ln\left(1-F_i^L\right)\Big], \quad (38)$$

$$\begin{aligned}\ln L^T &= \sum_{i=1}^{N}\Big[I_i^1 I_i^2 I_i^3 \ln F_i^{UU} + I_i^1 I_i^2\left(1-I_i^3\right)\ln\left(F_i^U - F_i^{UU}\right) + I_i^1(1-I_i^2)I_i^3 \ln\left(F_i^{UL} - F_i^U\right) + \\ &+ I_i^1\left(1-I_i^2\right)\left(1-I_i^3\right)\ln\left(F_i - F_i^{UL}\right) + \left(1-I_i^1\right)I_i^2 I_i^3 \ln\left(F_i^{LU} - F_i\right) + \\ &+ (1-I_i^1)I_i^2(1-I_i^3)\ln\left(F_i^L - F_i^{LU}\right) + \left(1-I_i^1\right)\left(1-I_i^2\right)I_i^3 \ln\left(F_i^{LL} - F_i^L\right) + \\ &+ \left(1-I_i^1\right)\left(1-I_i^2\right)\left(1-I_i^3\right)\ln\left(1-F_i^{LL}\right)\Big],\end{aligned} \quad (39)$$

$$\ln L^O = N \ln \frac{\pi}{\sqrt{3}} - N \ln \sigma - \sum_{i=1}^{N} q_i - 2\sum_{i=1}^{N} \ln(1 + e^{-q_i}), \quad (40)$$

where $F_i^{UU} = F_\varepsilon\left(d_i^{UU}\right), F_i^U = F_\varepsilon\left(d_i^U\right), F_i^{UL} = F_\varepsilon\left(d_i^{UL}\right), F_i = F_\varepsilon\left(d_i\right), F_i^{LU} = F_\varepsilon\left(d_i^{LU}\right), F_i^L = F_\varepsilon\left(d_i^L\right)$, $F_i^{LL} = F_\varepsilon\left(d_i^{LL}\right)$, and $d_i^{UU} = \left(\Delta e_i - A_i^{UU}\right)/\sigma, d_i^U = \left(\Delta e_i - A_i^U\right)/\sigma$, $d_i^{UL} = \left(\Delta e_i - A_i^{UL}\right)/\sigma$, $d_i = \left(\Delta e_i - A_i\right)/\sigma, d_i^{LU} = \left(\Delta e_i - A_i^{LU}\right)/\sigma, d_i^L = \left(\Delta e_i - A_i^L\right)/\sigma, d_i^{LL} = \left(\Delta e_i - A_i^{LL}\right)/\sigma$, and $0 < F_i^{UU} < F_i^U < F_i^{UL} < F_i < F_i^{LU} < F_i^L < F_i^{LL} < 1$ holds and $q_i = \frac{\pi}{\sqrt{3}\sigma} \times \left(Y_i - \Delta e_i\right)$.

The mean WTP and the confidence interval of mean WTP shown as equations (34) and (35) should be re-written as equations (41) and (42) below:

$$E(Y) = \bar{x}'\hat{\beta}_\Gamma, \ \Gamma = D, T, O \quad (41)$$

$$CI_{1-\alpha}[E(Y)] = \bar{x}'\hat{\beta}_\Gamma \pm t_{\alpha/2}\sqrt{\bar{x}'\Omega_\Gamma \bar{x}} \quad \Gamma = D, T, O, \quad (42)$$

where $\Gamma = D, T, O$. denotes data collected either from the second, third, or final elicitation decision process.

Additionally, $\bar{x}$ is a vector of mean values of all the explanatory variables, i.e., $\bar{x}' = (\bar{x}_1, \bar{x}_2, \bar{x}_3, \ldots, \bar{x}_K)$, where $\overline{x_j} = \sum_{i=1}^{N} x_{ij} \Big/ N$, $j = 1,2,3, \ldots, K$. $\hat{\beta}_\Gamma$ is a vector of estimated coefficients, and Ω_Γ is the asymptotic variance-covariance matrix of $\hat{\beta}_\Gamma$. Because $\left(\hat{\beta}_\Gamma, \hat{\sigma}_\Gamma\right)$ is a maximum likelihood estimator, $Var(\beta_\Gamma, \hat{\sigma}_\Gamma)$ will be approximated by the Cramer-Rao lower bound. That is,

$$Var(\hat{\beta}_\Gamma, \hat{\sigma}_\Gamma) = \begin{bmatrix} Var(\hat{\beta}_\Gamma) & Cov(\hat{\beta}_\Gamma, \hat{\sigma}_\Gamma) \\ Cov(\hat{\beta}_\Gamma, \hat{\sigma}_\Gamma)' & Var(\hat{\sigma}_\Gamma) \end{bmatrix} = \left[Inf^\Gamma(\beta, \sigma_\Gamma)\right]^{-1} \quad (43)$$

According to equation (43), Ω_Γ is equivalent to $Var(\hat{\beta}_\Gamma)$. By equation (42), it is known that

$$Var(\hat{\mu}_\Gamma) = \bar{x}' Var(\hat{\beta}_\Gamma)\bar{x}.$$

All estimated coefficients are presented in Table 6. The estimated mean WTP and its 95% confidence interval are then presented in Table 7. The empirical results shown in Table 6 and Table 7 have the same conclusion as those in which the respondents' socio-demographic variables are not specified. That is, the standard deviations of the estimated parameters μ and σ, the variances of mean WTP, and the ranges of the 95% confidence intervals all decrease as the choice stage increases. The variance of the final stage throughout the process designed in AIECVM drops dramatically both with and without the specification of socio-demographic variables. It is encouraging to know that the most efficient estimate of mean WTP emerges.

Conclusion

AIECVM is an elicitation method with a triple-bounded discrete choice followed by a continuous open willingness-to-pay revelation. With the aid of the first three stages of discrete choice, more respondents are encouraged to reveal their open-ended WTP. Moreover, AIECVM follows the C-optimal design criterion to assign the offered bid values, and one set of bids with seven bid amounts is obtained. The weakness of less variety in optimal design bid values can therefore be overcome by increasing the number of choice levels in AIECVM, which makes the bids designed by the optimal design criterion applicable in an actual survey. The most efficient improvement of the related welfare measurement can thus be used as the choice stage moves forward.

AIECVM is applied to the benefit evaluation of the black-faced spoonbill protected area. The results show that the variance of mean WTP decreases as the choice stage increases whether a response function is specified with respondent's socio-demographic variables or not. The ranges of the confidence intervals and the standard deviations of the estimated parameters also decrease as the stage increases. These empirical results are consistent with the theoretical deviations.

Table 6. Results of coefficients estimation for different decision process (with respondent's socio-demographic variables[a,b])

Variable	Decision process					
	Second stage		Third stage		Final stage	
Constant	-144.49 (207.17)		-130.67 (202.83)		-84.94 (177.37)	
Gender	-91.10 (54.96)	*	-86.32 (53.29)		-74.20 (47.01)	
Age	4.64 (2.70)	*	3.61 (2.66)		3.70 (2.35)	
Family	28.63 (13.65)	**	26.18 (13.19)	**	28.97 (11.73)	**
Edu	21.74 (9.78)	**	25.41 (9.68)	***	19.99 (8.31)	**
Income	0.23 (0.393)		0.33 (0.388)		0.39 (0.34)	
Known area	148.37 (57.68)	**	148.06 (55.68)	***	129.63 (49.19)	***
See	78.30 (84.84)		69.44 (83.69)		36.87 (74.28)	
Outdoor	97.12 (58.79)	*	99.99 (57.06)	*	79.02 (50.81)	
Green	121.40 (73.88)	*	110.29 (73.47)		109.31 (65.81)	*
σ	619.34 (33.01)	***	623.61 (26.09)	***	552.03 (19.96)	***
Log-L	-693.67		-1058.04		-4030.97	
X^2 (9)	39.79		40.60		42.08	

Note: [a]The total usable observations are 523. [b]Numbers in parentheses are standard deviations of estimated coefficients. Numbers with one asterisk indicate the coefficients are significantly different from zero at the 5% significant level. Numbers with two asterisks indicate the coefficients are significantly different from zero at the 1% significant level.

Table 7. Estimated mean WTP and 95% confidence interval of mean WTP (with respondent's socio-demographic variables)

Variable	Decision process[a]		
	Second stage	Third stage	Final stage
Mean WTP	590.62	613.04	589.68
Variance of mean WTP	750.89	701.22	548.23
95% confidence interval of mean WTP			
Lower bound	536.91	561.14	543.79
Upper bound	644.33	664.94	635.57
Upper bound–Lower bound	107.42	103.80	91.78
Upper bound / Lower bound	1.200	1.185	1.169

Note: [a]The exchange rate of US dollar to NT dollars was about 1:33 in the year of 1999.

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