

# “Adjusting benefits of mortality risk reductions using revealed and stated preference data”

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## Adjusting benefits of mortality risk reductions using revealed and stated preference data

### Abstract

One of the issues related to risk-benefit analysis is that a respondent's willingness to pay (WTP) is biased because they cannot always correctly perceive a small degree of risk. This study examines a method for adjusting perceived risks to calculate an exact option price. The main hypothesis of the model in this study assumes that the option price formulated by the integrating-back approach is equal to the WTP for a mortality risk reduction researched by the contingent valuation method. Three demand functions were employed for the formula. An empirical study was performed using data from both recreational activities and the mortality risk from water accidents at beaches in Miyagi prefecture, Japan. The estimated perceived risks ranged from 4.1 to 5.9 people per 380,000 people; however, the baseline risk presented in the questionnaire was 1.3 people per 380,000 people. The option prices calculated using 1.3 people per 380,000 ranged from 16 to 169 yen, and those calculated under the perceived risks ranged from 95 to 169 yen. As a result, the values of the option prices calculated under the individuals' perceived risks were shown to be higher than those calculated using the baseline risk.

**Keywords:** revealed preference data, stated preference data, option price, perceived risk.

**JEL Classifications:** Q26, Q51.

### Introduction

In environmental valuation studies, it is significant matter to calculate benefits of reductions of mortality risks from disease, natural disasters, traffic accidents, etc. The revealed preference data (hereafter, RPD) have been used for benefit calculations (e.g., Hanley et al., 2003; Bin et al., 2005; Whitehead et al., 2008). However, the calculations based on RPD are not appropriate or cannot apply for assessing mortality risk reductions due to a lack of probabilistic information. Thus, the stated preference data (hereafter SPD) have been mainly used for valuing the benefits under risks instead of RPD. Persson et al. (2001), Hultkrantz (2006), and Svensson (2009) calculated the benefits of mortality risk reductions in traffic accidents, Johansson (2002), Krupnik et al. (2002), and Houtven et al. (2008) calculated the benefits of mortality risk reductions in health status. The features of SPD are: (1) fixed mortality risks were presented, and (2) respondents were asked their willingness to pay (hereafter WTP) for the reduction rates (or amounts of reductions) of the risks.

In most studies, the values of mortality risks showed for respondents were extremely small. Thus, the following biases arise. One of the biases is scope insensitivity. Scope insensitivity is a bias where some respondents' willingness to pay did not change in accordance with the reduction rates due to extremely small risks (e.g., Heberlein et al., 2005; Goldberg and Roosen, 2007; Andersson and Lundborg, 2007). The second one is an ambiguity aversion. For example, if a respondent is not a good swimmer, they might answer with a high WTP value because they consider their mortality risk ( $\pi$ ) to be higher than the mortality risk

( $\bar{\pi}$ ; hereafter, baseline risk) presented in questionnaire.

This phenomenon, referred to as ambiguity aversion, is caused by the respondent's inability to correctly understand the mortality risk (see Ellsberg, 1961; Viscusi and Magat, 1992; Trautmann et al., 2008).

The purpose of this study is to examine a model of estimating a degree of ambiguity aversion, and to calculate the exact WTP under a risk without an ambiguity aversion effect by using RPD and SPD.

Treich (2010) performed a theoretical analysis on the influence of ambiguity aversion by using the concept of the value of statistical life (hereafter, VSL). Treich (2010) concluded that the ambiguity aversion leads to an increase in the respondent's WTP. In short, the respondent responds with a higher WTP for a mortality risk reduction rather than an exact WTP as judged by the baseline risk due to the "dead anyway" effect. This means that respondents increase their perceived risks by reference to the baseline risk. As a result, respondents' WTPs were overvalued WTPs.

Earlier studies that analyzed perceived risk or subjective probability (e.g., Viscusi, 1991; Savage, 1993; Lundborg, 2007; Chung et al., 2009) focused on estimating the perceived risk itself, and did not examine a model for adjusting the difference between a WTP calculated with the individual's perceived risk and a WTP calculated with the baseline risk (the presented risk in the questionnaire).

The remainder of this paper is organized as follows. In section 1, the formulation of option price (hereafter, OP) using the integrating-back approach (hereafter, IBA) is examined. In section 2, a model for estimating perceived risk is examined. In section 3, the details of the data are examined, and the results of estimations are shown in section 4. In section 5,

benefit calculations and the adjustment of WTP are performed with discussions. In the final section, the conclusions are described.

### 1. Theoretical background

**1.1. Definition of option price.** Weisbrod (1964), Jones-Lee (1976), and Graham (1981) performed some of the earlier studies on risk-benefit analysis. Weisbrod (1964) and Graham (1981) presented the concept of OP. Jones-Lee (1976) introduced the concept of VSL, which is defined as the marginal change of the (mortality) risk for OP. Since most early studies researched WTP for mortality risk using the concept of OP, the present study focused on the valuation of OP.

Let  $\pi$  be the probability of death (an individual's perceived risk) caused from a recreational activity, and let  $1-\pi$  be the probability of staying alive. Let  $\pi' = (1-r)\pi$  be the reduced mortality risk resulting from the implementation of DPCs. Here, let  $r$  be the risk reduction rate defined as  $r \in (0,1)$ . Let  $U_D$  be the individual's (indirect) utility when he is dead, and let  $U_A$  be the individual's utility when he is alive. Finally, let  $y$  be the individual's income. Freeman III (1999) formulated the OP for the risk reduction rate as shown in equation (1).

$$\pi U_D(y) + (1-\pi)U_A(y) = \pi U'_D(y - OP) + (1-\pi')U'_A(y - OP). \tag{1}$$

First, it is necessary to identify the indirect utility function. Although there are various ways to define the indirect utility function, the IBA, which was developed by Hausman (1981) and Larson (1992), was employed in this study. The IBA is used to derive the (quasi) indirect utility function from a demand function. For example, von Haefen (2007) derived several indirect utility functions using the IBA (the repackaging approach), and Whitehead et al. (2010) conducted an empirical study with the IBA.

**1.2. Integrating back approach.** This study used three types of demand functions – linear, semi-log, double-log – to derive the indirect utility functions in accordance with Hausman (1981). In an earlier study, Larson and Flacco (1992) examined models for estimating OP using the IBA. The formulations of OP from the three demand functions in this study referred Larson and Flacco's (1992) models. Here, preference parameters in the utility function such as recreational activities and income can be estimated using observed data. However,  $\pi$  cannot be estimated because it is difficult to observe information related to  $\pi$  in RPD. Thus, SPD is needed to estimate the value of  $\pi$ .

A model of using both RPD and SPD is necessary for the estimation. Cameron (1992) and Huang et al. (1997) performed studies to examine models that integrated both RDP (observed demands) and SPD

(WTP) in order to improve the accuracy of estimation of parameters in a demand function. Eom and Larson (2006) tested whether the weak complementarity, which is an assumption on a relationship between a demand and a quality, held or not by developing the models of Cameron (1992) and Huang et al. (1997). Eom and Larson's model (2006) improved upon the previous models by using an equation that made the WTP extracted from the SPD equal to the WTP formulated using the IBA. Following Larson and Flacco's formulations (1992) and Eom and Larson's model (2006), the hypothesis proposed in the present study is an equation between the WTP (i.e., OP) extracted from the SPD and the OP formulated using the IBA; this equation was used to estimate the perceived risk.

Let  $x$  be an individual's number of trips to a site,  $p$  be the generalized travel cost,  $y$  be the individual's annual income, and  $z$  be the individual's characteristic. Let  $\beta_p$  be the parameter of  $p$ ,  $\beta_y$  be the parameter of  $y$ , and  $\gamma$  be the vector of parameters for both a constant variable and  $z$ . From these variables and parameters, the linear demand function is defined as equation (2), the semi-log demand function is equation (3), and the double-log demand function is equation (4).

$$x = x^{LR}(\cdot) = \beta_p p + \beta_y y + \gamma z, \tag{2}$$

$$x = x^{SL}(\cdot) = \exp(\beta_p p + \beta_y y + \gamma z), \tag{3}$$

$$x = x^{DL}(\cdot) = \exp(\gamma z) p^{\beta_p} y^{\beta_y}. \tag{4}$$

Here, the superscript notations are used to indicate the type of demand function: *LR* means linear, *SL* means semi-log, and *DL* means double-log. These notations are also used for identifying the formulations of OP. According to Hausman's analysis (1981), the quasi indirect utility functions are derived as follows.

$$U = U^{LR}(p, y) = \frac{1}{\beta_y} \left( \beta_p p + \beta_y y + \gamma z + \frac{\beta_p}{\beta_y} \right) e^{-\beta_y p}, \tag{5}$$

$$U = U^{SL}(p, y) = \frac{1}{\beta_p} e^{\beta_p p + \gamma z} - \frac{1}{\beta_y} e^{-\beta_y y}, \tag{6}$$

$$U = U^{DL}(p, y) = -\exp(\gamma z) \frac{p^{1+\beta_y}}{1+\beta_y} + \frac{y^{1-\beta_y}}{1-\beta_y}. \tag{7}$$

Since a closed-form solution of the OP is needed to hold the hypothetical equation, a way to derive the closure forms of OP using these indirect utility functions was considered. Generally, it is difficult to derive the closure form of OP due to the two variables of the OP on the right side of equation (1). Here, Broome (1993) and Klose (2002), who considered the utility generated from a health status, observed that the utility of the dead should be zero in general. In accordance with their statements, let  $U_D$  equal zero. Thus, equation

(1) is rewritten as equation (10). The OP formulations in equations (11), (8), and (13) are derived from equations (5), (9), and (7), respectively.

$$(1 - \pi)U_A(p, y) = (1 - \pi')U'_A(p, y - OP). \quad (10)$$

$$OP^{LN} = \frac{(\pi - \pi')}{(1 - \pi')} \frac{1}{\beta_y} \left( x^{LR}(\cdot) + \frac{\beta_p}{\beta_y} \right). \quad (11)$$

$$OP^{SL} = \frac{1}{\beta_y} \ln \left( \frac{(\pi - \pi')(\beta_y / \beta_p)x^{SL}(\cdot) + (1 - \pi)}{(1 - \pi')} \right). \quad (12)$$

$$OP^{DL} = y - \left( \frac{1 - \pi}{1 - \pi'} y^{1 - \beta_y} + \left( \frac{\pi - \pi'}{1 - \pi'} \right) \left( \frac{1 - \beta_y}{1 + \beta_p} \right) \exp(\gamma z) p^{1 + \beta_p} \right)^{\frac{1}{1 - \beta_y}}. \quad (13)$$

Finally,  $\gamma z$  is defined as  $\gamma z = \beta_0 + \gamma_{gnd}GND + \gamma_{age}AGE$ . Here,  $\beta_0$  is a constant variable,  $GND$  is the individual  $i$ 's gender, and  $AGE$  is the individual  $i$ 's age. The parameters  $\gamma_{gnd}$  and  $\gamma_{age}$  modify the gender and age variables, respectively.

**1.3. Estimation model.** A modified version of Eom and Larson's estimation model (2006) was examined. In this study, the payment card format was used to

$$\ln \left( \prod_{i=1}^N \Pr(T_i | x_i) \right) = \sum_{i=1}^N \left( \begin{aligned} & -(1/2) \ln \{ 2\pi(1 - \rho^2) \} - \ln \sigma_\varepsilon + \frac{1}{2} \left( 1 - \frac{1}{(1 - \rho^2)} \right) \left( \frac{(\xi_i - \mu_\xi)^2}{\sigma_\xi^2} \right) \\ & - \frac{1}{2(1 - \rho^2)} \left( \frac{(\varepsilon_i - \mu_\varepsilon)^2}{\sigma_\varepsilon^2} - \frac{2\rho(\xi_i - \mu_\xi)(\varepsilon_i - \mu_\varepsilon)}{\sigma_\xi \sigma_\varepsilon} \right) \end{aligned} \right). \quad (14)$$

Next, let  $\alpha$  be a parameter and defines  $\pi \equiv \bar{\pi} \times \ln(1 + \alpha)$ . Here,  $\pi$  is an individual's perceived risk, as discussed above, and  $\bar{\pi}$  is the mortality risk presented in the questionnaire (i.e.,  $\bar{\pi}$  is the baseline risk). If  $\alpha = 0$ , then  $\ln(1 + \alpha) = 0$ , so  $\alpha = 0$  means that the mortality risk  $\pi$  does not influence the WTP. If  $\alpha > \exp(1) - 1 \approx 1.7182$ , then the aggregated individuals' perceived risks are greater than the baseline risk. Otherwise,  $\alpha < 1.7182$  means that the perceived risk is less than the baseline risk.

**2. Data and estimation results**

**2.1. Data.** *2.1.1. Overview.* The data on recreational activities at 25 beaches in Miyagi prefecture, Japan were used for the estimation. There were 382,420 total users for all sites in 2009 according to data from the Miyagi Prefectural Government, and the National Police Agency stated that there were eight deaths related to water accidents. These accidents were not limited to those that occurred during recreational activities at beaches.

The research for this study was conducted through an Internet research company from January to February 2010. An e-mail was sent to about 10,000 respondents, and 3,401 respondents answered

In this study, the payment card format was used to indicate WTP. Let  $T_i$  be individual  $i$ 's WTP, let  $\mu$  be the parameter, and let  $\varepsilon_i$  be a disturbance term. Let us assume that  $T_i = (1 + \mu)OP_i + \varepsilon_i$ . Here,  $OP_i$  is defined by equations (11)-(13). Thus, the parameter  $\mu$  is the difference between  $T_i$  and  $OP_i$ , and the true OP ( $\overline{OP}$ ) is defined as  $\overline{OP} = (1 + \mu)OP_i$ . If  $\mu$  equals -1, there is no relationship between the WTP and the OP.

Respondents answered their WTP given a number of trips,  $x$ . Thus, let  $\Pr(T_i | x_i)$  be the conditional probability of choosing  $T_i$ . Let  $\xi_i$  be the disturbance term in a demand function:  $x = x(\cdot) + \xi_i$  for the linear type, and  $\ln x = x(\cdot) + \xi_i$  for the semi-log and double-log types. Let  $\phi(\cdot)$  be the marginal distribution; consequently,  $P(T_i | x_i) = \phi(x_i) / P(T_i, x_i)$  holds from Bay's rule. Let us assume that  $\varepsilon_i$  and  $\xi_i$  follow the bivariate normal distribution,  $N(0, 0, \sigma_\varepsilon^2, \sigma_\xi^2, \rho)$ , with different parameters ( $\sigma_\varepsilon$  and  $\sigma_\xi$ ) and a correlation  $\rho$ . Thus,  $\phi(\cdot)$  becomes the normal density function. Then, the log likelihood function, with the total number of  $N$  respondents, is defined as equation (14).

screening questions that asked whether they had lived in Miyagi prefecture, and whether they had visited at least one beach in Miyagi prefecture in the past year. After the screening, the remaining 914 respondents were invited to complete an online questionnaire. Eventually, 763 respondents answered the questionnaires. There were some respondents whose number of visits was extremely high (over 100 times). It was difficult to estimate parameters when the data for these respondents were included. In addition, they would not be judged as popular users. Therefore, 35 respondents, which represented 5% of all respondents, were excluded. Finally, the 728 remaining respondents' data were used for the estimation. Table 1 shows the basic statistics of the data.

Table 1. Statistics

Symbols	Units	Mean	Standard deviation
$x$	Times	3.548	3.090
$d$	Km	33.740	26.749
$t$	Minutes	65.097	44.609
$p$	Yen	1726.849	1222.011
$y$	Thousand yen	5736.264	3137.027
$WTP$	Yen	977.060	1749.870
$GND$	1: male, 0: female	0.598	0.491
$AGE$	Years	40.210	9.290
$N$	728		



2.1.2. *Revealed preference data.* The RPD used in the estimation were individuals' total number of visits to beaches in past a year, annual income, gender, and age. An individual  $i$ 's total number of visits ( $x_{ij}$ ) is defined as sum of all their visits to beach sites.  $y_i$  is the individual  $i$ 's annual household income. The individual  $i$ 's travel cost to site  $j$  ( $p_{ij}$ ) was calculated by  $p_{ij} = 2 \times (103.9 \times d_{ij} / 16.5 + 10 \times t_{ij})$ . The distance  $d_{ij}$  (km) from the individual  $i$ 's home to the  $j^{\text{th}}$  beach and the trip time ( $t_{ij}$ ) were calculated using the respondent's ZIP code and the Japanese electronic map computer software program Zenrin Z Professional 7. The figure of 10 yen/min was used as the opportunity cost for the trip. The figure of 103.9 yen/liter was the average cost of gasoline in 2009. The figure of 16.5 km/liter was the average fuel consumption of gasoline per kilometer in 2008. Finally, data on the individual  $i$ 's gender (1 for male and 0 for female) and age (actual years) were collected by the research company.

2.1.3. *Stated preference data.* As mentioned above, it was difficult to obtain information on the number of deaths related to recreational activities at beaches. Thus, the number of dead persons in a year was set at eight according to the data of the National Police Agency in 2010. Since the total number of beach users was 382,420 persons according to the government data, then the mortality risk was calculated as 8/382,420 persons. However, all eight deaths were not caused by recreational activities at the beach. Thus, the mortality risk was adjusted by changing the denominator from 382,420 to 2,340,029, which was

the population of Miyagi prefecture in 2009. That is, the mortality risk was redefined as 8/2,340,029 persons. Finally, 1.3 people per 380,000 people, which was simplified from 8/2,340,029 to a number that was closer to the total number of users at beaches, was presented in the questionnaire. Furthermore, the Miyagi Coast Guard Office reported that there were two swimming-related deaths in 2009. Thus, the mortality risk figure presented in this research was not larger than the actual value of mortality risk (1.6/380,000). Therefore, there were no overestimations of WTP caused by excessive computation of the presented mortality risk in the questionnaire.

The details of the SPD are shown in Appendix. The risk reduction rates presented in the questionnaire were 10%, 50%, and 90%, and individuals' WTP for each reduction rate were determined using the payment card format. From these data, the WTP for a 50% reduction rate was employed for this case study. Thus, the mortality risk when a project was implemented was calculated as  $\bar{\pi}' = 0.5 \times \bar{\pi}$ . Since the payment for WTP was established as a one-time occurrence, a unit of WTP calculated in this study is yen per one time.

### 3. Estimation results

The statistical software  $R$  was used for the estimation. The `optim`, which is a function of  $R$ , was used. The optimization method was the Broyden-Fletcher-Goldfarb-Shanno method. The results are shown in Table 2.

Table 2. Estimation results

Parameters	Model					
	Linear		Semi-log		Double-log	
	Estimates	P-value	Estimates	P-value	Estimates	P-value
$\beta_0$	7.01071	0.000	0.43719	0.000	-0.06667	0.587
$\beta_p$	-0.00056	0.000	-0.00001	0.000	-1.00126	0.000
$\beta_y$	-0.00002	0.000	0.00003	0.001	0.69104	0.000
$\gamma_{gnd}$	1.07590	0.000	0.16174	0.002	-0.03830	0.495
$\gamma_{age}$	0.08196	0.000	0.00368	0.198	0.00839	0.005
$\alpha$	22.17701	0.073	90.04957	0.000	35.77220	0.000
$\mu$	-30.76145	0.000	-37.02838	0.000	48.65189	0.000
$\rho$	-0.99898	0.000	0.99983	0.000	0.99998	0.000
$\sigma_\xi$	-87.73836	0.000	36.48846	0.000	-114.3790	0.000
$\sigma_\epsilon$	234.20410	0.000	35.86720	0.000	9.99861	0.000
Max. LL	-2666.561		-1254.439		-87.381	
AIC	5353.122		2528.878		194.762	
N	728		728		728	

First, the signs of  $\beta_p$  for every model were negative, and the  $p$ -values were less than 1%. Second, the signs of  $\beta_y$  were negative for the linear demand function and positive for the semi-log and the double-log demand functions; all the  $p$ -values for  $\beta_y$

were less than 1%. Therefore, the parameter  $\beta_y$  for the linear demand function was not consistent with the ordinal theory of benefit analysis. Third, the signs of  $\gamma_{gnd}$  were positive for the linear and semi-log demand functions, and they were negative for the

double-log demand function. The  $p$ -values for both the linear and semi-log demand functions were less than 1%; conversely, that of the double-log demand function was over 1%. Thus, the  $\gamma_{gnd}$  of the double-log demand function was not considered to be statistically significant. The signs of  $\gamma_{age}$  were positive for all models. The  $p$ -values for both the linear and double-log demand functions were less than 1%; conversely, that of the semi-log demand function was over 1%. Thus, the  $\gamma_{age}$  of the semi-log demand function was not considered to be statistically significant.

The signs of  $\alpha$  were positive in all models. The  $p$ -values were less than 1% for the semi-log and double-log demand functions; but they were over 1% for the linear demand function. Thus, the  $\alpha$  of the linear demand function was not considered to be statistically significant. The individuals' perceived mortality risks (per 380,000) calculated from both the values of  $\alpha$  and the equation  $\pi = \bar{\pi} \times \ln(1 + \alpha)$  were 4.1 per 380,000, 5.9 per 380,000, and 4.7 per 380,000 for the linear, semi-log, and double-log demand functions, respectively. The results indicate that individuals perceived higher mortality risks than the baseline risk presented in the questionnaire (1.3 per 380,000). A possible cause for the high rates of individuals' perceived mortality risk may be ambiguity aversion. There is the possibility that there are other causes, but further research is needed to identify them.

The signs of  $\mu$  are negative for the linear and semi-log demand functions, and they are negative for the double-log demand function. Since the  $p$ -values are less than 1% for every model, it is considered that there are differences between the WTP and the OP formulated by the IBA for all models. There is a possibility that the cause of the differences is the formulation of the OP. If this is the case, it would be necessary to seek other suitable formulations.

The estimation results indicate that some parameters would not be statistically significant. However, all parameters were employed for the benefit calculation to avoid a change in the values of benefits due to a lack of parameters.

### 5. Benefit calculations and discussion

Benefit calculations were performed according to two steps. In the first step, the individuals' WTP were calculated by applying the observed data and estimated parameters to  $(1 + \mu)OP$ . In the second step, the mean values of the WTP were defined as final results. The results are shown in Table 3. The values in brackets are the WTP per dollar, which was calculated by using an exchange rate of 93.54 yen per dollar (Japan Foreign Trade 2010), which was the average value of exchange rates in 2009.

Table 3. Calculations

	Questionnaire	Linear	Semi-log	Double-log
$\pi$ (per 380,000)	1.3	4.1	5.9	4.7
$WTP_{\pi}$ yen [dollar]	-	531 [5.67]	95 [1.02]	124 [1.33]
$WTP_{\bar{\pi}}$ yen [dollar]	-	169 [1.81]	16 [0.17]	35 [0.37]
$WTP_{\mu=0}$ yen [dollar]	-	-14 [-0.14]	-3 [-0.03]	3 [0.03]

The first row of Table 3 shows the calculated values of  $\pi$ .  $WTP_{\pi}$  in the second row indicates the WTP calculated using the values in the first row. The maximum value of  $WTP_{\pi}$  is 531 yen for the linear demand function, next is 124 yen for the double-log demand function, and finally the minimum WTP of 95 yen for the semi-log demand function. The calculation results indicate that the benefits calculated from the different demand functions differ as with the case of calculating the values of consumer surplus by using different demand functions.  $WTP_{\bar{\pi}}$  in the third row shows the WTP calculated by adjusting the values of individuals' perceived mortality risks to 1.3 per 380,000. The maximum value is 163 yen for the linear demand function, then 35 yen for the double-log demand function, and finally 16 yen for the semi-log demand function. All values of  $WTP_{\bar{\pi}}$  become smaller than those of  $WTP_{\pi}$  due to the adjustments of mortality risks from  $\pi$  to  $\bar{\pi}$ . The results indicate that a decrease in the value of mortality risk leads to a decrease in the value of OP. This is consistent with the theory of VSL. Finally,  $WTP_{\mu}$  in the fourth row indicates the WTP calculated using the estimated values of  $\pi$  in the first row and  $\mu=0$ . The values of  $WTP_{\mu}$  become smaller than those of  $WTP_{\pi}$  by adjusting  $\mu=0$ . Moreover, the  $WTP_{\mu}$  for the linear and semi-log demand functions become negative. These results indicate that the parameter  $\mu$  is an adjustment factor for this model.

### Concluding remarks

The perception of small risk is a significant issue in risk-benefit analysis. A respondent's inability to correctly perceive risk results in a bias in their willingness to pay (WTP). Ambiguity aversion, which is a phenomenon where the respondent provides a high value for WTP due to their difficulty in perceiving the small risk, is considered to be one such bias. The purposes of this study are: (1) to examine a benefit calculation method to estimate the value of mortality risk perceived by respondents; and (2) to calculate the exact WTP without bias (e.g., ambiguity aversion) by adjusting the perceived mortality risks.

The option price (OP) was researched for the benefit calculation. The main hypothesis of the estimation model assumed equality between the OP formulated by three types of demand functions and the value of WTP for a mortality risk reduction researched by the contingent valuation method. That is,  $WTP = (1 + \mu)OP$  was assumed ( $\mu$  is a parameter). Linear, semi-log, and double-log demand functions were used to formulate the OPs. The perceived mortality risks in the OPs were set as one of the parameters.

Data on recreational activities at the beaches of Miyagi prefecture, Japan were employed. The mortality risk, which was used in the contingent scenario, was caused by water accidents at beaches. The research was conducted through an Internet research firm. In the WTP questionnaire, the mortality risk, which was calculated using government data, was 1.3 people per 380,000 people (the baseline risk), and the data on the WTP for a 50% reduction in the mortality risk was used for estimation.

As a result, the perceived mortality risks were estimated at 4.1 per 380,000, 5.9 per 380,000, and 4.7 per 380,000 for the linear, semi-log, and double-log demand functions, respectively. The results indicate that the respondents adjusted their WTP to one more appropriate for a higher mortality risk than the baseline risk. OPs were calculated using the estimated mortality risks and demand functions. Three categorized OPs were calculated. The first case was the OP calculated using the estimated mortality risks. The second case was calculated by converting the esti-

mated mortality risks into the baseline risk. The third case was calculated under a restricted parameter condition,  $\mu = 0$ . The difference between the first case and the second case is the main argument of this study. The WTP calculated from the first case was 591 yen, 95 yen, and 124 yen for the linear, semi-log, and double-log demand functions, respectively. In the second case, the WTP was 169 yen, 16 yen, and 35 yen for the linear, semi-log, and double-log demand functions, respectively. The OPs of the first case were larger than those of the second case. These results indicate that the respondents' WTP was high, and the OPs shrink as the estimated mortality risks are converted into the baseline risk.

There are several potential criticisms that can be made regarding the current study. The first is that only the integrating-back approach was used to formulate the OP. There are other methods (e.g., identifying an indirect utility function directly) to formulate the OP and the perceived mortality risks. Thus, the method used in this study could be used as one of formulations to adjust the perceived mortality risk. The second criticism is that there was no analysis of the cause of perceived higher mortality risks. There is a possibility that multiple biases were the cause (e.g., the framing effect analyzed by Tversky and Kahneman, 1981). Regarding this point, another study should be implemented to identify the cause or causes. In any case, the bias that generated the respondents' misperception of the mortality risk was adjusted by using the model of this study.

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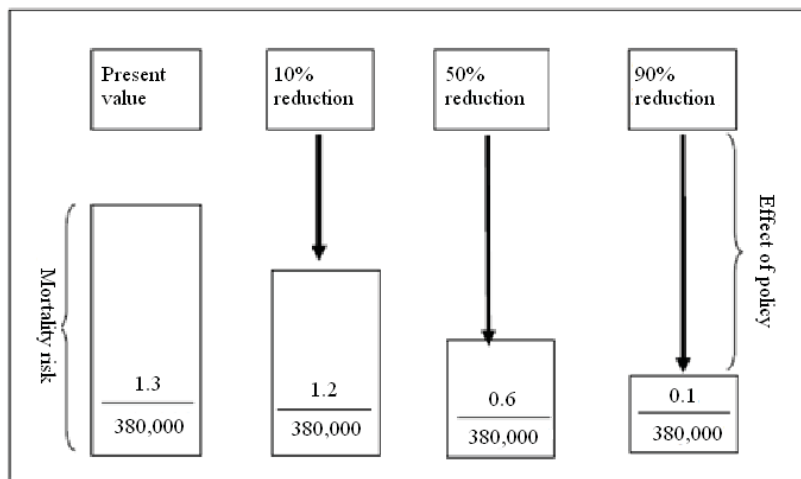
**Appendix**

**1. Stated preference data.** Smith and Desvousges (1987) and Corso et al. (2001) pointed out that it is difficult for respondents to perceive the magnitude of risk reduction. Thus, they recommended using figures that show the magnitudes of risks in order to make respondents understand them more easily. In this study, two figures were employed. One was employed to show the relative magnitudes of mortality risks, and the other was employed to show the effects of projects (on prevention measures) on mortality risk reductions.

Table 1 which shows the mortality risks for cancer, traffic accidents, fire (only buildings), and water accidents per year. On the left hand side of Table 1, the mortality risk per 100,000 people is shown. Since the mortality risk of water accidents was calculated as 1.3 per 380,000, this figure was used on the right hand side of Table 1.

Table 1. Mortality risks per 100,000 and 380,000 people

Mortality risks per 100,000 people		Mortality risks per 380,000 people	
Causes	Number of death	Causes	Number of death
Canser	266.9 persons	Canser	800.7 persons
Traffic Accident	4.1 persons	Traffic Accident	15.58 persons
Fire(only bulding)	0.98 persons	Fire(only bulding)	3.7 persons
Water accidents	0.34 persons	Water accidents	1.3 persons



**Fig. 1. Risk reduction rates**

Figure 1 shows the mortality risks for water accidents and the corresponding effects of reductions in rates. The reduction rates, i.e., the effect of projects intended to prevent accidents, were set at 10%, 50%, and 90%. These reduction rates were determined from the preliminary survey of this study. In the preliminary survey, the reduction rates of 10%, 30%, 50%, 70%, and 90% were presented. However, there were few differences between the mean values of 10% and 30% and between the mean values of 50% and 70%. Since respondents were confused by the similarities between the aforementioned values, the reduction rates of 10%, 50%, and 90% were selected for this study. The magnitudes of mortality risk reductions are shown by each bar in Figure 1. The current mortality risk (1.3 per 380,000) is on the left hand side of the figure. The next bar shows the mortality risk reduced by 10%. Similarly, the values for 50% and 90% are also shown in order.

The contingent scenario for asking WTP is presented below.

Let us assume that you use beaches as you have during the past a year over the next 10 years. Currently, preservation countermeasures against water accidents are performed at beaches, but the mortality risk is 1.3 persons per 380,000 persons in a year. Although the mortality risk cannot be eliminated completely, it can be reduced by performing additional preservation countermeasures such as an increase in the number of life savers, safety nets, or emergency medical personnel, etc.

Since additional funds are needed to implement these additional preservation countermeasures, let us assume that a tax for the preservation countermeasures is collected. The tax is collected from residents of Miyagi prefecture in order to maintain or improve the preservation countermeasures. The uses of the collected tax are as follows:

1. The tax is used for preservation countermeasures at beaches.

The duration of the proposed project is 10 years from now. The tax is used to provide additional manpower and life-saving supplies for the protection of beachgoers.

2. The tax is a one-time transaction. The effect of the preservation countermeasures lasts 10 years.
3. All the funds are used for preservation countermeasures only. The details of the accounting are published.

Since there was a possibility that respondents would imagine the resulting situation to be the same as their current circumstances if the project was short, the duration of the project was set at 10 years. This was done in the hope that respondents would provide their WTP after imagining different circumstances than their current ones. As for the people who should pay the tax, beachgoers are the intended target of the prevention countermeasures, but every beach is open to all citizens, so it would be impractical to attempt to collect an admission fee. Therefore, a tax for residents living in Miyagi prefecture was assumed.

In an empirical study, a 10 year duration would create many difficulties. For simplicity's sake, let us assume that an individual's utility is the same for 10 years and there is no change in their income or the distribution and consumption of goods. Then, the individual's option price is defined as follows. Here,  $\rho$  is the individual's discount factor, and  $t = 10$ .

$$(1 - \pi) \{1 / (1 + \rho^{t-1})\} U_A(\cdot, y) = (1 - \pi) \{ \rho / (1 + \rho^{t-1}) \} U_A(\cdot, y) + U_A(\cdot, y - OP). \tag{A.1}$$

This formulation indicates that the WTP data researched in this study would include information related to time preference. Earlier studies such as Viscusi and Moore (1989), Alberini et al. (2006), and others discussed this point. However, the estimation model becomes more complex when the factor of time preference is included (i.e., the number of payments would be set at 10 times). Moreover, additional information on the time preference would be necessary to estimate  $\rho$ .

Since the benefit analysis based on the stated preference data is defined as an ex ante evaluation, the issue of time preference occurring in most of the previous studies is generally neglected, and the OP is evaluated using equation (1). Since it is difficult to distinguish and estimate both mortality risk and time preference simultaneously, this study followed a similar approach. Furthermore, the formulation  $WTP = (1 + \mu)OP$  is assumed in this study, and  $\pi$  is included in the formulation of the OP. Thus, it is considered that the information on time preference was reflected in the value of  $\mu$ .

*Answer format*

Although single- and double-bounded formats are commonly used in CVM, it was difficult to create programs in this format due to the systems employed by the research company used in this study. Consequently, this research used the payment card format. Moreover, since three reduction rates (10%, 50%, and 90%) were assumed in this study, then the answer format was designed as the matrix shown in Table 2. Evans (2003) and Broberg and Brännlund (2008) performed similar studies using this kind of matrix for their answer format. The reduction rates are indicated on the rows and the WTP (0; 100; 300; 500; 1,000; 3,000; 5,000; 7,000; 10,000) are shown on the left-hand column. All respondents provided their WTP for reduction rates by checking (✓) the appropriate box in the matrix.

There were four responses for 0 yen. (A) 0 yen: This project has no meaning, (B) 0 yen: I have no money, (C) 0 yen: There is no way that I will get into an accident, (D) 0 yen: I dislike the tax. If a respondent selected A or B, their WTP was classified as 0 yen. If they chose C or D, their WTP was classified as a protest because the response objected to the payment vehicle or the mortality risk in question.

Table 2. Matrix type's answer format

WTPs (yen)	Reduction rate (%)		
	90%	50%	10%
10,000			
7,000	✓		
...	...	...	...
2,000		✓	
...	...	...	...
100			✓
0			