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Non-Market Valuation of Water Pollution Remediation and Disaster Risk Mitigation Functions: The Case of Nakdong River Estuary in South Korea

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Abstract: The Nakdong river estuary in South Korea has two important functions: first, remediating water pollution from the Nakdong river; second, mitigating the risk of disaster caused by waves from the open sea. The two functions of the Nakdong river estuary have been continuously threatened due to constant development pressure. This short note tries to investigate the non-market value of the water pollution remediation and disaster risk mitigation functions. For this purpose, 1000 households throughout the country were randomly selected, and a choice experiment (CE) survey of them was implemented in September 2017. The two attributes considered here are water pollution remediation and disaster risk mitigation. An increase in the yearly income tax was also considered as an attribute. The results of applying the CE approach show that the non-market values of a 1%p increase in the water pollution remediation ability and a 1 m decrease in the wave height of the estuary are KRW 105 (USD 0.09) and KRW 501 (USD 0.44), respectively, per household per year. These figures can be used to establish and execute marine spatial planning for the estuary.

Keywords: Nakdong river estuary; non-market value; willingness to pay; choice experiment

1. Introduction

An estuary is a place where the river meets the sea and has independent value as a third space distinguished from rivers and seas. The Nakdong river estuary in South Korea, where the Nakdong river originates from Gangwondo and meets the sea, is composed of large and small deltas, such as Eulsukdo, Daemadeung, and Jangjado Baekhapdeung, which are produced by the thick sediment transported by the river [1–3]. The estuary provides the spawning places and natural habitats for a number of marine plants and animals. The estuary also contributes to improving the quality of life by providing Busan citizens with the space for ecological learning and experience.

Due to these characteristics, the estuary was designated as a Cultural Property Protection Area by Korea Ministry of Culture, Sports, and Tourism in 1966, a Natural Environment Conservation Area by Korea Ministry of Oceans and Fisheries in 1998, a Wetland Conservation Area by the Ministry of Environment in 1999, and a Special Coastal Pollution Control Sea Area in Busan by Korea Ministry of Oceans and Fisheries in 2000. In spite of that, the estuary has been continuously threatened by many development projects along the Nakdong river. Thus, the South Korean government is establishing and implementing management plans for conserving the ecosystem of Nakdong river estuary to prevent environmental damage that can be caused by development projects [4,5]. In particular, the government has established Master Plans for Wetland Conservation, Total Pollution Load Management Project, and Water and Environmental Management Plan to remediate water pollutants.

Information about the non-market value of the estuary is widely demanded to secure relevant budgets and forming a public consensus, both of which are crucial to the successful implementation of the management plan. Moreover, it is necessary for conducting a cost-benefit analysis of any development project that might have negative effects on the ecosystem of the estuary. The economic values of most functions of the estuary have been measured in the literature or can be easily assessed, but two functions have not been valued in the literature and cannot be easily valued. Therefore, the government is demanding information about the non-market value of the water pollution remediation and disaster risk mitigation functions provided by the estuary.

The two functions are remediation of water pollution from the Nakdong river and mitigation of disaster risk caused by waves from the open sea. The estuary has an extensive tidal flat capable of remediating water pollutants. This tidal flat has a water pollution remediation capacity up to 80 times higher than the Ganghwa-do tidal flat and five times higher than the Masan bay tidal flat in Korea [6,7]. Furthermore, the estuary has large and small deltas arranged along the east-west direction and serving as a breakwater to block waves coming from the open sea [8,9].

Among the variety of functions provided by the estuary, this article is interested in these two functions. More specifically, this article attempts to investigate the non-market value of the two functions. There are some earlier related studies that have looked into the intangible value of the estuary including the water pollution remediation function and disaster risk mitigation function, which cannot be evaluated in the market [8–16]. From the literature review, the authors decided to employ a choice experiment (CE) approach to carry out the investigation. The CE technique has been widely utilized in valuing a non-market good with multiple attributes [17–25].

The economic value arising from water pollution remediation function and disaster risk mitigation function can be assessed using the costs of constructing and operating the sewage treatment plant, and the costs of constructing and operating the seawall or breakwater, respectively. That is, a replacement cost approach is applicable. However, from an economics point of view, the replacement cost approach should be used only in limited ways because it is a cost and cannot be economic value. In other words, it is necessary to apply appropriate economic techniques such as CE approach to assess non-market values for the two functions provided by the estuary.

Therefore, the primary purpose of this short note is to measure the non-market value of the water pollution remediation and disaster risk mitigation functions of the estuary using the CE technique. The remainder of the note has three parts. The second part describes the methodology used in the note. The results are provided and discussed in the third part. Conclusions are given in the fourth part.

2. Methodology

2.1. CE Approach

The CE approach collects data from a survey of randomly selected respondents using the random utility model [26,27]. In general, three or four alternatives, which include the status quo alternative, are offered to an interviewee in the survey. Interviewees are faced with alternatives consisting of several attributes to be valued and price attribute. The interviewees choose the most favorite alternative among several alternatives. Usually, interviewees would make four to eight choices. Investigating the trade-off between individual attribute and price attribute can give us information about the marginal willingness to pay (MWTP) to raise or lower the level of individual attribute [28].

2.2. Attributes

Attributes refer to the detailed characteristics of which a good or service of interest is valued. Therefore, the first thing to do in carrying out a CE application study is to make a list of attributes. The level of individual attributes should then be defined and properly scoped. Attributes should be meaningful to people who do valuations. This means that attributes should be easily explained to people and understood by people. Moreover, it should be possible to control the level of attributes by government policy. Two attributes used in this study are water pollution remediation and disaster risk mitigation, as presented in Table 1. Price attribute, a rise in annual income tax, is also considered for the purpose of obtaining the MWTP values for the two attributes.

The authors have sought advice from marine water quality experts on how much water pollution remediation ability of the Nakdong river estuary will be reduced if tidal flat of the estuary is damaged and its function is degraded. The experts included professors of oceanography at university and doctors at the ocean-related research institute. Overall, they advised that the water pollution remediation ability could be reduced by up to 30%. Therefore, the level of the attribute for water pollution remediation is described as the percentage of improvement in the water pollution remediation ability in a baseline state where the water pollution remediation ability is reduced by 30% due to damage to the tidal flat compared to the current water pollution remediation ability. The baseline state of this attribute is 0%, which means that there is no improvement in water pollution remediation ability. The upper bound of this attribute is 30% if there is an improvement in the water pollution remediation ability by increasing the tidal flat areas in the Nakdong river estuary. Thus, the worst condition was set at this level and this condition indicates the baseline state. The level of an attribute for disaster risk mitigation is specified as the decrease in wave height in a baseline state where the wave height is increased by 2 m due to damage to the delta compared to the current wave height. The baseline state of this attribute is 2.2 m if the delta in the estuary disappears. The delta in the estuary can reduce the wave height by up to 0.2 m.

Table 1. Attributes used in this study.

Attributes	Description	Levels
Water pollution remediation	Percentage of improvement in water pollution remediation ability in a baseline state where water pollution remediation ability is reduced by 30% due to damage to tidal flat compared to current water pollution remediation ability (unit: %)	Level 1: 0% # Level 2: 10% Level 3: 30% *
Disaster risk mitigation	Decrease in wave height in a baseline state where wave height is increased by 2 m due to damage to delta compared to current wave height (unit: meters)	Level 1: 2.2 m # Level 2: 1.5 m Level 3: 0.2 m *
Price	Willingness to pay for remediating the water pollution and mitigating the disaster risk of Nakdong river estuary through an increase in the annual income tax per household (unit: Korean won)	Level 1: 0 # Level 2: 1000 Level 3: 2000 Level 4: 4000 Level 5: 7000

Notes: # and * indicate the baseline state and the current state of each attribute. At the time of the survey, KRW 1000 = USD 0.88.

The numbers of levels of Water pollution remediation attribute, levels of Disaster risk mitigation attribute, and levels of price attribute are 3, 3, and 4, respectively. Thus, the number of possible alternatives generated from Table 1 amounts to 45 (= 3 × 3 × 5). However, it is not necessary or appropriate to present all these alternatives to the respondents because of the respondents' bounded rationality and time/cost constraints. An orthogonal main effect design was implemented, and sixteen alternatives were obtained. They were randomly mixed and then divided into eight sets of two alternatives. One choice set is composed of Alternative A, Alternative B, and baseline state alternative as shown in Table 2. Thus, there were eight choice sets, which were divided into two groups of four. Each respondent would randomly belong to one of the two groups. In other words, each respondent was assigned to either Group A or Group B, was presented with four choice sets, and was required to perform a task of selecting one alternative among the three alternatives with the given choice set. Note that the first two levels of Water pollution remediation attribute, levels of Disaster risk mitigation attribute in Alternative B of Choice set 3 in Group A and Alternative B of Choice set 1 in Group B are coincidentally the same as a result of orthogonal main effect design. However, since the two alternatives belong to different groups, there is no case for a respondent to judge them together. The main part of the survey questionnaire in this study is given in Appendix A. Figure A1. is an example of choice card we present to the respondents.

Table 2. Each choice set presented to each interviewee.

			Attributes		
			Water Pollution Remediation (unit: %)	**Disaster Risk Mitigation (unit: m)**	**Price [a]**
Group A	Choice set 1	Alternative A	0%	0.2 m	2000
		Alternative B	10%	2.2 m	2000
		Baseline state	0%	2.2 m	0
	Choice set 2	Alternative A	0%	1.5 m	1000
		Alternative B	10%	1.5 m	7000
		Baseline state	0%	2.2 m	0
	Choice set 3	Alternative A	0%	1.5 m	7000
		Alternative B	30%	2.2 m	7000
		Baseline state	0%	2.2 m	0
	Choice set 4	Alternative A	10%	1.5 m	1000
		Alternative B	30%	0.2 m	4000
		Baseline state	0%	2.2 m	0
Group B	Choice set 1	Alternative A	0%	1.5 m	2000
		Alternative B	30%	2.2 m	2000
		Baseline state	0%	2.2 m	0
	Choice set 2	Alternative A	10%	0.2 m	7000
		Alternative B	10%	2.2 m	4000
		Baseline state	0%	2.2 m	0
	Choice set 3	Alternative A	30%	1.5 m	7000
		Alternative B	10%	2.2 m	1000
		Baseline state	0%	2.2 m	0
	Choice set 4	Alternative A	10%	1.5 m	1000
		Alternative B	0%	0.2 m	2000
		Baseline state	0%	2.2 m	0

Notes: [a] The unit is Korean won. At the time of the survey, KRW 1000 = USD 0.88. Each respondent is assigned to either Group A or Group B, is presented with four choice sets, and is required to perform a task of selecting one alternative among three alternatives with the given choice set.

2.3. Utility Function

According to usual practices in the literature, a linear form of the utility function is assumed. The levels of water pollution remediation, disaster risk mitigation, and price are Y_1, Y_2, and Y_3, respectively. Let C be a dummy for an interviewee's selecting the status quo alternative. W_{ab}, which is defined as the utility when respondent a chooses alternative b, has the form:

$$W_{ab} = C_a + \delta_1 Y_{1,ab} + \delta_2 Y_{2,ab} + \delta_3 Y_{3,ab} + \lambda_{ab} \quad (1)$$

where λ_{ab} is a disturbance term and the δ's are the parameters to be estimated.

Let T_1 and T_2 be the MWTP for one unit increase in water pollution remediation and the MWTP for one unit decrease in disaster risk mitigation, respectively. If we omit ab in Equation (1) for brevity, the microeconomics theory indicates that the MWTP values are derived as:

$$T_1 = \partial \frac{\partial W/\partial Y_1}{\partial W/\partial Y_3} = \partial \frac{\delta_1}{\delta_3} \text{ and } T_2 = \frac{\partial W/\partial Y_2}{\partial W/\partial Y_3} = \frac{\delta_2}{\delta_3}. \quad (2)$$

2.4. How to Obtain the Utility Function

In order to obtain the utility function given in Equation (1), we should estimate the δ values. The most widely used model in the literature for this purpose is the multinomial logit (MNL) model. The model was originally proposed by McFadden [29] and has nice merit of proving us a closed form of a log-likelihood function as:

$$\ln L = \sum_{a=1}^{A} \ln \left[\frac{\prod_{d=1}^{3} \left(\exp(W_{ad})\right)^{I_{ad}}}{\sum_{e=1}^{3} \exp(W_{ae})} \right] \quad (3)$$

where A is the number of interviewees and I_{ab} is a dummy for interviewee a's choosing alternative b. The parameter values maximizing Equation (3) comprise the utility function given in Equation (1) [30].

3. Results and Discussion

3.1. Estimation Results

A nationwide CE survey of 1000 randomly chosen households was undertaken by a professional polling firm through person-to-person interviews during September 2017. Each household gave us four observations. Thus, we would get a dataset size of 4000 (1000 × 4). Table 3 gives the estimation results of the MNL model. Interestingly, the sign of coefficient estimate for water pollution remediation is positive. Improvement in the water pollution remediation ability from the baseline state rises raises the utility. However, the coefficient estimate for disaster risk mitigation has a negative sign. Thus, decreasing the wave height increases the public utility. The coefficient for Price also has a negative sign, which means that the price has a negative relation to the utility.

Table 3. Estimation results of the utility function.

Variables [a]	Coefficient estimates [c]	
C [b]	−0.927 [#]	(−15.50)
Water pollution remediation	0.016 [#]	(8.53)
Disaster risk mitigation	−0.077 [#]	(−2.68)
Price	−0.155 [#]	(−12.55)
Sample size	4000	
Log-likelihood	−4138.65	
Wald statistic [d] (p-value)	456.78	(0.000)

Notes: [a] the definitions of the variables are given in Table 1. [b] C is a dummy for the interviewee's selecting the status quo alternative. [c] [#] indicates statistical meaningfulness at the 1% level and t-values are in parentheses on the right side of the estimates. [d] The null hypothesis is that the estimated utility function isn't significant.

3.2. Discussion

Using Equation (2), we can compute the MWTP values. Table 4 presents the results of estimating the MWTP values. The MWTP estimates for a 1%p increase in water pollution remediation ability and a 1 m decrease in wave height are KRW 105 (USD 0.09) and KRW 501 (USD 0.44), respectively, per household per year. These values mean the non-market values of the two functions supplied by Nakdong river estuary in South Korea.

Table 4. Marginal willingness to pay (MWTP) estimates.

Attributes	MWTP Estimates Per Household Per Year
An increase in water pollution remediation (unit: %p)	KRW 105 [#] (USD 0.09)
A decrease in disaster risk mitigation (unit: m)	KRW 501 [#] (USD 0.44)

Notes: [#] denotes statistical meaningfulness at the 1% level. At the time of the survey, USD 1.0 = KRW 1,136.

We can estimate the non-market value, which is combinations of these attributes using the MWTP estimates for an increase or decrease in the attributes. If we multiply the figures given in Table 4 by the levels of attributes, the non-market value of the alternative for the hypothetical state of the Nakdong river estuary is obtained. As a result, Table 5 showed the non-market value for the situations in which the two functions of the Nakdong river estuary are improved. To illustrate this process, the authors arbitrarily compose three hypothetical situations using the information given in Table 1. For example, Situation A means that 10%p improvement in the water pollution remediation function and no improvement in disaster risk mitigation function because wave height does not decrease from the baseline state. The non-market value per household per year for improving the current state to

Situation A from the baseline state is calculated to be KRW 1,050 (USD 0.92) increase in annual income tax. A more detailed calculation process is as follows:

$$\text{KRW 105 (USD 0.09)/\%p} \times 10\%\text{p} + \text{KRW 501 (USD 0.44)/m} \times 0\ \text{m} = \text{KRW 1,050 (USD 0.92)}. \quad (4)$$

The annual national value computed for each alternative using the number of total households are provided in Table 5. South Korea had a total of 19,523,587 households in 2017 [31]. We find that the annual national value of the Situation A is computed as KRW 20.50 billion (USD 18.05 million).

Table 5. Results of computing non-market value for the situations in which the two functions of the Nakdong river estuary are improved.

Attributes	Situation A	Situation B	Situation C
An increase in water pollution remediation (unit: %p)	10%p	10%p	30%p
A decrease in disaster risk mitigation (unit: m)	0 m	0.7 m	2.0 m
The non-market value per household per year for the above improved situation expressed in an increase in the annual income tax	KRW 1050 (USD 0.92)	KRW 1401 (USD 1.23)	KRW 4152 (USD 3.65)
Annual national value	KRW 20.50 billion (USD 18.05 million)	KRW 27.35 billion (USD 24.08 million)	KRW 81.06 billion (USD 71.36 million)

Notes: At the time of the survey, USD 1.0 = KRW 1,136. South Korea had 19,523,587 households in 2017 [31].

What the respondents performed was to select one of the three alternatives. Table 5 shows the total WTP or total non-market value to change from the current state to the improved state when assuming a specific situation in which the two functions of the Nakdong river estuary are improved. Therefore, the alternative is the object of the CE work required for the respondents in the survey, and the situation is considered as an illustrating example related to the utilization of the analysis results.

The results reported above have various potential uses. First, the results can be utilized to assess external costs due to development projects affecting the water pollution remediation function and/or the disaster risk mitigation function of the estuary. In the context of economics, external costs must be properly internalized to achieve economic efficiency. To do so, it is necessary to know the exact magnitude of external costs. In other words, when internalizing the externalities by imposing environmental taxes on a development project that adversely affect the environment of the Nakdong river estuary, the value of external costs incurred by the development project must be known in order to obtain the magnitude of the optimal tax. For example, an environmental impact assessment of a project to install offshore wind power generators at the estuary shows that the development is expected to result in decreases in water pollution remediation and disaster risk mitigation abilities of the estuary. At this time, the government should impose environmental taxes to correct externalities. The results of this study can easily provide an answer to the question of how large the optimal tax is.

Second, the results can be adopted as a basis for securing justification for the investment required to enhance the water pollution remediation function and/or the disaster risk mitigation function of the estuary. Large investments are needed to implement a project of improving the water pollution remediation function and/or the disaster risk mitigation function of the estuary. The funds required for the investments will eventually be borne by the people, and the project is just one of many projects the government will have to perform. Therefore, the economic feasibility of the project should be assessed, rather than putting public funds into it unconditionally. That is, only when the benefits ensuing from an investment should be greater than the costs involved in the investment this investment can be socially justified. If the costs are greater than the benefits, it is preferable not to carry out the project. Whereas costs can usually be measured relatively easily, it is not easy to evaluate the benefits of an investment. However, the results of this study can be used to estimate the economic benefits of a project that improves the two functions of the estuary.

Third, the results can be employed as a basis for determining the appropriate level of such investments. Suppose we can set ecologically desirable levels of the water pollution remediation function and the disaster risk mitigation function of the estuary. Or, suppose that there are levels of the water pollution remediation function and the disaster risk mitigation function that local residents or the government want. The government needs information about how much investments are desirable to achieve the levels. In other words, an upper limit on the level at which investments are allowed is required. This is because it would be nice to invest a lot, but the government has a lot of projects to do and a limited budget to invest. The results of this study may then be used as a socially acceptable cap on investments.

4. Conclusions

This note aimed to examine the non-market value of water pollution remediation and disaster risk mitigation functions in the Nakdong river estuary. To this end, the CE technique was adopted. The coefficients for the utility function were statistically significant when estimated by applying the MNL model. The results showed that an increase in the water pollution remediation ability and a decrease in the wave height increase the utility. More specifically, the non-market values for a 1%p increase in the water pollution remediation ability and a 1 m decrease in the wave height were measured as KRW 105 (USD 0.09) and KRW 501 (USD 0.44), respectively, per household per year.

This note described some useful policy implications related to the management and conservation of the Nakdong river estuary. In particular, South Korean central and local government officials were urgently requiring information about the non-market value of the two functions of the estuary in establishing and implementing a marine spatial plan for the estuary. This is because the estimated non-market values are essential information for evaluating whether a new development project on the estuary is socially profitable or not. For instance, these findings can help determine whether a new project should be implemented by comparing the benefits arising from the project implementation with the economic damage to the estuary that is caused by the project.

This note seems to contribute to the literature in a research perspective. The note utilized a CE technique to look into the non-market values of two functions provided by the estuary and found that the utilization was successful because the estimation results were statistically meaningful and the respondents actively participated in the CE survey without any difficulties. So far as the authors know, this note is the first to measure the non-market values of two functions provided by an estuary. It is necessary to compare our results with the results from applying the CE approach to other estuaries in South Korea. It would also be meaningful to explore the source of the difference if there is a difference. Comparison of the results from our work with those from future works that will be applied in other countries will yield new implications. Furthermore, this note employed the MNL model, which is most widely used in empirical studies because it is relatively simple and easy to apply. However, our results need to be compared with the results from employing other models that can be applied to dealing with the CE data.

Author Contributions: All the authors made important contributions to this paper. H.-J.K. worked to draft and refine questionnaire for CE application to collect data, and created more than half of the manuscript; J.-I.C. carried out the literature review and determined the levels of the attributes; and S.-H.Y. was responsible for designing and applying the economic and statistical models needed for obtaining the results.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Main Part of the Survey Questionnaire

Part 1. Questions About Socio-Economic Characteristics

The interviewees were asked to respond to their socio-economic characteristic such as the gender of the individual, the number of family members, the level of education, and the monthly income per household (before tax deduction). Questions about the number of family and income were open-ended questions, and the question about the level of education was as follows:

Q1. Please check with √ your education level in years.

Education level	Uneducated	Elementary school	Middle school	High school	University	Graduate school
Education level in years	0	1 2 3 4 5 6	7 8 9	10 11 12	13 14 15 16	17 18 19 20

Part 2. Questions about marginal willingness to pay

Type A. Q1. Check with √ the only available alternative that you prefer among Alternative A, B, or the baseline state.

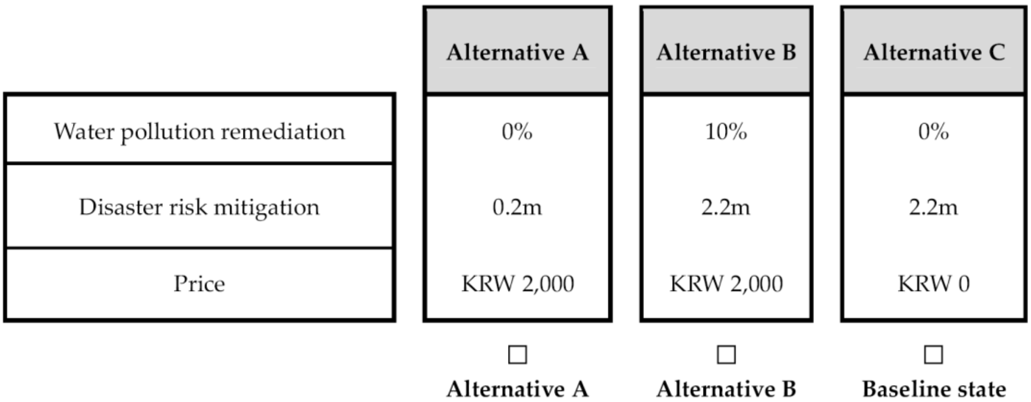

Figure A1. A sample choice set used in this study.

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